# EFFECT OF TEMPERATURE ON SEVERAL CHARACTERISTICS OF SUMMER RAPE (BRASSICA NAPUS L.)

by

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## ABSTRACT

Two experiments were conducted to determine if seed size, oil content, iodine number of oil, and protein content of rapeseed could be modified by subjecting rape plants to various temperature - time treatments from early bolting till maturity. Results from constant temperature treatments from both experiments show that seed size and oil content of rapeseed and iodine number of rapeseed oil could be decreased, whereas protein content was increased by exposing rape plants to high temperature from early bolting till maturity. This was generally also true for variable temperature treatments.

Results from variable temperature treatments of both experiments show that characteristics of rapeseed were more susceptible to temperature treatment during terminal than during initial periods.

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# INTRODUCTION

Fussel (8) stated that rape (Brassica napus L.) has been grown in Europe since the 17th century and according to White and Bolton (20) the crop was not grown commercially for production of oil in Canada until 1942 when World War II cut off rapeseed oil imports from Oriental countries. Subsequently, advances in technologies of the food processing industries coupled with demands to fulfill requirements for edible oils of the rapidly multiplying human population of our world have spurred further interest in rapeseed production in Canada. The Commonwealth Economic Committee (3) reports that since 1955 Canada has been the world's "largest shipper of rapeseed". Thus in a short period Canada's role changed from importer to major exporter of rapeseed.

The rapid rise in the importance of the rapeseed crop in Canadian agriculture warrants an ecological study of summer rape. Knowledge about the impact of an environmental variable such as air temperature during seed development stage on the quality and quantity of seed components could be of importance in making recommendations to growers and for the integration and interpretation of results obtained from field trials. Consequently, a project was undertaken to determine the associations of several controlled temperature - time treatments with oil and protein metabolism in developing seed of summer rape.

## LITERATURE REVIEW

Although studies have been made on the effect of different environments on oilseed crops such as soybeans and flax, very little has been done regarding the relationship between environment and the composition of rapeseed.

Prior to 1914 Garner et al. (9) noted from general observations that seeds produced under different conditions frequently varied in composition to such an extent that their commercial value was affected. Therefore they (9) undertook to "ascertain so far as possible the most favourable conditions for obtaining maximum yields of oil" in soybeans and cotton-seed by making studies on the effect of location, soiltype, climate, and fertilizers, in modifying oil content and seed size. The studies revealed that: 1) Differences in oil content and seed size existed between locations; 2) oil content and seed size of soybeans grown in large tile cylinders filled with the same soil type and set into the ground at different locations, varied with location and year; 3) oil oil content was reduced by the addition of nitrogen, and increased by the addition of phosphorus, but was not affected by potassium; 4) phosphorus increased seed weight, but nitrogen and potassium were ineffective in this respect. Garner et al. (9) concluded that under practical field conditions climate was more effective than soil type in controlling oil content and seed size, but because of the "interdependence of soil and climate" with respect to temperature and water

supply, it is difficult or impossible to develop far-reaching generalizations as to the effect of either independently of the other on plant development".

For several years after the work of Garner et al. (9), the study of environmental effects on oilseed crops by several investigators (7, 13, 14) was centered on the effects of mineral and organic fertilizers and soil type on protein content and oil content of soybeans. The studies are of particular interest because they disclosed that protein content as well as oil content can be influenced by soil fertility, and that soil treatments which increased protein content invariably decreased oil content.

Stark (15) reported in 1924 on a study dealing with the effect of soil type not only on both oil and protein contents of soybeans, but also with the effect of soil type on iodine number of soybean oil. His data (15) show that both oil and protein content of 4 varieties of soybeans differed between locations that differed in soil reaction. Acid soils were associated with high oil and low protein, whereas high lime soils were associated with low oil and high protein. Stark (15) generalized that variability in the amount of oil and protein in soybeans was probably not so much due to "geographic position or climatic conditions but rather to the plant food available and to soil reaction". However, the generalization is of limited value, firstly,

because the data are from a single year of trials only, and secondly, the paper contains no information about climatic conditions during the experiment. Furthermore, the separation of available plant food and soil pH is not entirely justified, because the availability of plant nutrients may depend on soil pH. With regard to iodine number Stark (15) found that there was considerable variation within varieties but it was not consistent enough to indicate whether location or soil type was responsible. The inconsistent data on iodine number may have been due to interaction of soil and climate.

Cartter and Hopper (2) made a 5 year study of environmental effects on seed components of 10 varieties of soybeans at 5 locations. Components studied were oil content, protein content, and iodine number of the oil. An analysis of variance of each of the 3 seed components revealed significant (.01 level) mean squares for varieties, location, years, and location x years. Significant variances for years, and location x years indicates that climate as well as soil was effectual in making up the mean squares due to location.

In another experiment Cartter and Hopper (2) observed the effect of 4 soil fertility levels on protein content, oil content, and oil iodine number of 8 varieties of soybeans during 3 seasons. Analysis of variance of protein data revealed a non-significant mean square for years, but mean mean squares for varieties, levels of soil fertility, and

varieties x years were significant. Evidently there was no difference between year means, however the significant varieties x years interaction indicates that some of the means of individual varieties differed between years, suggesting that climate can affect protein content. However, since the variance for years was non-significant whereas the mean square for levels of soil fertility was highly significant it appears that soil fertility was more important than climate in controlling protein content. For both oil content and iodine number of oil, years and varieties each contributed considerably more to variation than did fertility levels, though all 3 sources of variation were statistically significant. Therefore, it appears that climate had a greater effect than soil fertility on oil content and iodine number of soybean oil.

In order to determine the effect of a single climatic factor, Weiss et al. (18) correlated some seed compositional characters of 5 varieties of soybeans with temperatures during the pod filling period. Temperature differentials during the seed filling stage were controlled by planting at 4 successive 11-day intervals at each of 3 locations in three successive years. They (18) found that for both early and late varieties of soybeans a positive correlation existed between oil content and mean temperature for the period of from 50% flowering until maturity. The association of protein

and oil content was negative. Weiss et al. (18) found that mean temperature during seed development was negatively correlated with iodine number of soybean oil.

In an effort to discover during which stage of seed development oil production of soybeans is most sensitive to temperature differentials, Howell and Cartter (11) determined correlation coefficients between temperature and oil content of several varieties of soybeans for 10-day periods from 50 days before maturity until maturity. They (11) found that oil content and temperature were most closely correlated 20-30 days before maturity, suggesting that the influence of temperature was greatest at that time.

More recently, Howell and Cartter (12) used growth chambers to determine whether oil content of soybeans could be changed by controlling temperature during all or part of the pod filling stage. They (12) found that the oil content averaged 23.2, 20.8, and 19.5 per cent when the day temperatures of 85°, 77°, and 70° F. respectively, were used constantly during the entire pod filling stage. When the temperature was elevated to 80° F. from 70° F. for one week during the fourth, fifth, sixth, or seventh week before maturity an oil content of about 22 per cent resulted, as compared to 19.6 per cent when the temperature was elevated during the second week before maturity. These data indicate that oil content of soybeans is sensitive to temperature differentials for as short a period as one week during pod filling, and that a

critical period for oil formation exists from 4 to 7 weeks before maturity.

A study by Hopper and Johnson as summarized in Experiment Station Records (5) deals with the effect of climate on iodine number and quantity of oil in flaxseed. Their (5) data, gathered from United States Department of Agriculture reports and from commercial analysis covering the period 1911-1937, show that in North Dakota and Minnesota oil content and oil iodine number of flaxseed were negatively correlated with mean July temperature. Experiment Station Records (6) report that similar results were obtained by Dillman and Hopper who studied the effect of climate on oil content and iodine number of flaxseed. Based on the results of a 1-10 years cooperative tests at 54 experimental stations representing most of the flax growing areas in the United States, Dillman and Hopper's (6) project disclosed that in the North Central States both deficient rainfall and high July temperatures were negatively correlated with oil content and with iodine number. Crude protein content of flaxseed was negatively correlated with precipitation, and positively with July temperature.

In general, high temperature during seed development can result in depressed iodine numbers of soybean oil and of flaxseed oil. Oil content of flaxseed was depressed whereas oil content of soybeans was increased by high temperature during seed development.

## MATERIALS AND METHODS

In 1959-60 two experiments were carried out at the University of Manitoba to determine whether the oil and protein contents of rapeseed and iodine number of rapeseed oil could be altered by controlling temperatures during seed development. Temperatures were maintained by use of plant growth chambers manufactured by Coldstream Refrigeration Company. Lighting in each chamber was provided by 32 General Electric FR 96T12 C.W. fluorescent lamps and 7 Westinghouse 60 watt incandescent lamps. The centre line of the gabled lamp hood was suspended 40 inches above the pots. There was no provision for the control of relative humidity.

### Experiment I

Three hundred 7 inch clay pots were filled with a uniform mixture of 5 parts clay loam and 1 part sand. On May 25, 1959 these pots were seeded with Golden rape and placed in a sheltered place outdoors. The resulting seedling stand was thinned to 5 plants per pot. At the early bolting stage 150 of the pots were selected, and subsequently assigned to one of 15 groups of 10 pots each. Each pot of plants in a group was selected for the resemblance of height and number of leaves of its plants to those of a pot of plants in each of the other groups. On July 7 the material was transferred into growth chambers.

Plants were watered as needed. In general, while in

the growth chambers this meant adding 10 ounces of water every 72 hours to each pot kept at 55° F., every 48 hours to pots at 70° F. and alternate 32 and 40 hours to pots kept at 85° F.

The photoperiod of all treatments was 13 hours.

Each group of plants was subject to a specific temperature - time treatment. For the sake of brevity each treatment will be described by a coded expression. Each expression has been divided into three terms e.g. 55-70-70. The first and the second terms each represent an 11-day interval. The third term represents the time remaining till maturity. The numbers represent temperatures in degrees Fahrenheit during particular time intervals. The coded expressions that will be used hereafter to describe treatments of Exp. I are given in Table I below.

TABLE I Coded expressions describing temperature - time treatments of Exp. I

| | | |
|---|---|---|
| 55-55-55 | 70-70-70 | 85-85-85 |
| 55-55-70 | 70-70-55 | 85-85-55 |
| 55-70-70 | 70-55-55 | 85-55-55 |
| 55-55-85 | 70-70-85 | 85-85-70 |
| 55-85-85 | 70-85-85 | 85-70-70 |

Consideration of Table I shows that in some treatments a temperature change was made immediately after the first

11-day interval, whereas in other treatments a temperature change was made after the first and the second 11-day intervals had lapsed. Thus a particular treatment may be described as one that had an 11-day initial period e.g. 55-70-70, or had a 22-day initial period e.g. 55-55-70. The third interval will be referred to as a terminal period regardless of duration.

Data regarding 100-seed weight, oil and protein contents of rapeseed, and refractive index of rapeseed oil were collected from each treatment.

Experiment II

In Exp. II the type of soil, type of pot, seed lot, number of pots seeded, method of selection, and type of growth chambers were the same as those used in Exp. I. However, in Exp. II five grams of fertilizer consisting of equal parts of 16-20-0 and 0-0-60 was placed one inch below the seed in each pot. Pots were seeded on August 14 and placed outdoors. Subsequent seedling stands were thinned to three plants per pot. The material was transferred to growth chambers on October 14.

Enough water was added to keep the soil surface moist at all times. In general this meant that plants at 70° F. and 80° F. were watered every day and plants at 60° F. were watered every two days. The amount of water added was not

measured, but was usually just sufficient to bring the moisture level up to the water holding capacity of the soil.

The photoperiod for all treatments was 15 hours.

Each group of plants was subjected to a particular temperature - time treatment. For the sake of brevity and clarity each treatment will be described by a coded expression. Each expression has been divided into three terms e.g. 80-60-80, each term representing a period of time. The numbers describe in degrees Fahrenheit the temperature during a specified time period. The first or initial period represents the time required for the plants to develop from beginning of bolting till end of flowering. The second interval or middle period represents a 10-day interval following end of flowering. The third or terminal period represents the time remaining till maturity. Obviously treatments such as 80-60-60 had only initial and terminal periods. The coded expressions that will be used hereafter to describe treatments are given in Table II below.

TABLE II Coded expressions describing temperature - time treatments of Exp. II

| | | |
|---|---|---|
| 60-60-60 | 70-70-70 | 80-80-80 |
| 60-70-60 | 70-60-70 | 80-60-80 |
| 60-70-70 | 70-60-60 | 80-60-60 |
| 60-80-60 | 70-80-70 | 80-70-80 |
| 60-80-80 | 70-80-80 | 80-70-70 |

Consideration of coded expressions in Tables I and II reveals that some treatments did not have a temperature change e.g. 55-55-55 and 60-60-60. These treatments will be referred to as constant temperature treatments. Treatments that had one or more temperature changes will be referred to as variable temperature treatments. Data from constant temperature treatments provided a means of determining the overall effects of a particular temperature on various components of rapeseed, and also provided a standard for evaluating results from variable temperature treatments. Data from variable temperature treatments provided a means of measuring the effects of a specific temperature on various seed components during a particular time period.

Data regarding 100-seed weight, oil and protein content of rapeseed, refractive index and calculated iodine number were collected from each treatment.

## Statistical Techniques

### Design and Analysis

The design of both experiments was an incomplete factorial. Data were analysed as in a completely randomized design. Error terms were derived from variations between determinations on samples treated alike. Differences between all treatment means pertaining to a particular seed component were tested for significance at the 5% level by Hartly's

sequential method as outlined by Snedecor (16).

Sampling

A single 100-seed weight was determined for each of the 10 pots of plants in a treatment[1]/. For per cent oil content determination the rapeseed from adjacent pots in a treatment was bulked and approximately one gram of seed was analysed from each of the five bulked samples. A single refractive index reading was determined for each sample of rapeseed oil. Per cent protein determinations were made on two seed residue samples per treatment.

Laboratory Techniques

Seed Size

Pods were harvested into paper bags and subsequently stored for one week at room conditions before they were threshed. A separate bag was used for each pot of plants, thus 10 samples of seed were collected from each treatment. A single 100-seed weight was made from each sample of seed.

Oil Content Determination

The method used for determining oil content of the rapeseed was similar to that described by Comstock and Culbertson (4), with the exception of the following modifications: 1) before pressing, the seed was oven-dried at 105° C. for 15 hours; 2) a crushing pressure of 11000 pounds per square inch was applied for one minute to a

1/ For exceptions see Appendix A and B

measured volume of approximately one gram of rapeseed; 3) seed residue, after the third decantation, was air-dried for 24 hours, and then oven-dried at 105° C. for 15 hours.

Oil content was calculated from the difference between the dry weight of the sample of whole seed and the dry weight of the seed residue left after oil extraction. Difference in weight was attributed to the oil that had been extracted.

Refractive Index and Calculation of Iodine Number of Rapeseed Oil

The solvent and oil mixture resulting from three successive decantations was air-dried for 24 hours followed by drying in a vacuum oven for 1 hour at 40° C. After cooling to room temperature a drop of oil was placed in a Bellingham and Stanley No. 465415 refractometer that had a prism temperature of 35° C. One minute was allowed for temperature equilibration of oil and prism before a reading was taken.

Refractometer readings were converted into iodine numbers utilizing the formula $12873.58 \times (n^{25} + .0036) - 18831.54 = I.N.$ as described by Anderson (1), where $n^{25}$ equals the refractometer reading with a prism temperature of 25° C. and .0036 is a correction factor required for a prism temperature of 35° C.

Protein Content of Rapeseed Residue

Seed residue remaining after oil extraction was used for determination of protein content. Two samples of seed

residue were chosen at random from each treatment. All residue in a sample (approximately 0.5 gm.) was analysed for nitrogen by the Kjeldahl Method (10). Seed residue was digested in 20 ml. concentrated $H_2SO_4$ in the presence of one package of Kel-Pak no. 4 2/, for 40 minutes. After digestion 65 ml. of a solution containing 45% (wt./vol.) NaOH and 3.6% (wt./vol.) $Na_2S_2O_3 \cdot 5H_2O$ were added. The amount of $NH_3OH$ was estimated by titrating with .0571 N NaOH. The protein content was calculated by multiplying the $N_2$ content by the factor 6.25.

2/ Kel-Pak is manufactured by Harshaw Scientific Co.

## RESULTS AND DISCUSSION

Results and Discussion has been divided into four main sections namely: Seed Size, Oil Content, Iodine Number, and Protein Content, and are dealt with in that order. In each section, results from Experiments I and II are discussed separately but are compared in a brief summary.

Constant temperature treatments of Experiments I and II provided a means of observing the overall effects of several different temperatures on synthesis of various components in rapeseed, and provided a basis for interpretation of results from variable temperature treatments. Variable temperature treatments provided a means for observing the effects of increased and decreased temperature on rapeseed components during initial, middle (Exp. II only), and terminal periods of treatments.

## Seed Size

Rapeseed size expressed as grams per 100 seeds is a measure of the total amount of material anabolized into the seed. It follows that a variation in seed size associated with a change in level of an environmental factor such as temperature could imply that elaboration of one or more seed constituents was affected by temperature. Data in Tables III and IV show that the range of Experiment I seed sizes measured in grams per 100 seeds was 0.2786, and in Experiment II the range was 0.1219. The relatively large ranges indicate that temperature - time treatments affected the seed size of rapeseed.

### Experiment I

#### Constant Temperature Treatments

The strongly negative association between seed size and temperature when a uniform temperature was maintained from bolting to maturity is illustrated by data from Table III where comparisons of size of seed from constant temperature treatments were:

| | |
|---|---|
| 55-55-55 | 0.3405 gm. |
| 70-70-70 | 0.2978 gm. |
| 85-85-85 | 0.1724 gm. |

The rapeseed from the intermediate (70° F) and higher (85° F) temperature treatments were 12.5% and 49.4% smaller, respectively, than the seeds from the low (55° F) temperature treatment. Thus the depressing effect of high temperature on seed size was much greater than that of an intermediate temperature.

TABLE III Size of rapeseed (grams per 100 seeds) from temperature - time treatments of Exp. I

| Treatment1/ Degrees F. | X-X-55 | X-55-55 | X-X-70 | X-70-70 | X-X-85 | X-85-85 | Row mean |
|---|---|---|---|---|---|---|---|
| 55-55-X | .3405 | | .2986 | | .2179 | | .2857 |
| 55-X-X | | .3405 | | .2875 | | .1409 | .2563 |
| 70-70-X | .3738 | | .2978 | | .3138 | | .3285 |
| 70-X-X | | .3685 | | .2978 | | .1507 | .2723 |
| 85-85-X | .4195 | | .3406 | | .1724 | | .3108 |
| 85-X-X | | .4142 | | .3201 | | .1724 | .3022 |
| Column Mean | .3779 | .3744 | .3123 | .3018 | .2347 | .1547 | |

1/ Treatments are coded as indicated in a three term expression X-X-X representing temperature treatments during initial and terminal periods. The middle term can be part of either initial or terminal period, depending on duration of initial period.

Variable Temperature Treatments

The variable temperature treatments in Exp. I were arranged so that each treatment consisted of only two different temperature periods (Table III). Thus for purposes of discussion the middle term of the three part expression can be combined with either the first or third period to give an 11-day initial or a 22-day initial period.

Temperature during terminal periods tended to be negatively associated with seed size. The ranges of seed size, in grams per 100 seeds, for the three terminal temperatures (long and short initial periods combined) reveal the nature

of the association:

| | |
|---|---|
| X-X-85°F. | 0.1409 - 0.3138 |
| X-X-70°F. | 0.2875 - 0.3406 |
| X-X-55°F. | 0.3405 - 0.4195 |

Except when followed by 85° F. terminal temperature there was little difference between the effect of long and short initial periods on seed size. Seeds from 22-day initial (55° F. or 70° F.) and 85° F. terminal treatments were approximately twice the size of those from the corresponding 11-day initial periods (Table III).

Temperatures during long and short initial periods of the three temperatures were not closely associated with seed size. The wide ranges of seed size for the three initial temperatures which follow illustrate this point:

| | |
|---|---|
| 85°F.-X-X | 0.1724 - 0.4195 |
| 70°F.-X-X | 0.1507 - 0.3738 |
| 55°F.-X-X | 0.1409 - 0.3405 |

The overlapping of these ranges suggest that initial temperatures have much less effect on seed size than terminal temperatures.

The effect of combinations of initial and terminal temperatures must also be considered. Study of Table III reveals that a high temperature followed by an intermediate or low temperature and an intermediate temperature followed by a low temperature invariably resulted in larger seed than the corresponding intermediate or low temperature for the

entire period from bolting to maturity. The data in Table III also shows that a low temperature followed by a high temperature resulted in smaller seed than the corresponding low or intermediate temperature used for the entire period from bolting to maturity. Thus the results of the variable temperature treatments can be summarized as follows: A period of relatively high temperature followed by a period of lower temperature tends to increase seed size while a period of relatively low temperature followed by a period of higher temperature tends to decrease seed size.

## Experiment II

### Constant Temperature Treatments

The results of the constant temperature treatments (Table IV) in this experiment confirmed results obtained in Exp. I. The effect of temperature on size of rapeseed is illustrated by:

| | |
|---|---|
| 60-60-60 | 0.3376 gm. |
| 70-70-70 | 0.3060 gm. |
| 80-80-80 | 0.2292 gm. |

The seeds from the intermediate temperature (70° F.) and high temperature (80° F.) were 6.5% and 32.2% smaller, respectively, than seeds from the low (60° F.) temperature treatment. The range of temperatures was smaller than in Exp. I so the smaller ranges in seed sizes was expected. The strong negative association between seed size and a

uniform temperature from bolting to maturity was confirmed by this experiment.

TABLE IV Size of rapeseed (grams per 100 seeds) from temperature - time treatments of Exp. II

| Treatment 1/ Degrees F. | X-60-60 | 60-X-60 | X-70-70 | 70-X-70 | X-80-80 | 80-X-80 | Row mean |
|---|---|---|---|---|---|---|---|
| 60-X-X | .3376 | | .3419 | | .2692 | | .3162 |
| X-60-X | | .3376 | | .3163 | | .2652 | .3064 |
| 70-X-X | .3227 | | .3060 | | .2855 | | .3047 |
| X-70-X | | .3434 | | .3060 | | .2215 | .2903 |
| 80-X-X | .3333 | | .3343 | | .2292 | | .2989 |
| X-80-X | | .2941 | | .2722 | | .2292 | .2652 |
| Column Mean | .3312 | .3250 | .3274 | .2982 | .2613 | .2386 | |

1/ Treatments are coded as indicated in a three term expression X-X-X representing temperature treatments during initial and terminal periods. The middle term can be part of either initial or terminal period, depending on duration of initial period.

Variable Temperature Treatments

In Exp. II each time - temperature treatment consisted of two temperatures. One series of treatments consisted of initial and terminal periods comparable to those used in Exp. I. In the other series initial and terminal temperatures were the same while the middle period temperature was varied.

Temperature during the terminal periods was negatively associated with seed size in much the same way as in Exp. I. Again temperatures during initial periods did not seem to influence seed size to any marked degree. There was a tendency

toward smaller seed size when periods of low temperature were followed by a higher temperature. This tendency was not quite as consistent as in Exp. I. High temperatures during intial periods followed by lower temperatures in terminal periods did not result in increased seed size as it did in Exp. I. Temperatures during the middle period were negatively associated with seed size.

Summary

There was a high negative association between a uniform temperature from bolting to maturity and seed size in both experiments.

High terminal temperatures were strongly associated with small seed size in both experiments.

Initial temperatures seemed to have relatively little effect on seed size.

Initial periods of relatively low temperatures followed by a higher temperature generally resulted in smaller seed than from the corresponding low (or intermediate) temperature treatment.

Initial periods of relatively high temperatures followed by a lower temperature generally resulted in larger seed than from the appropriate low (or intermediate) temperature in Exp. I. This phenomenon was not observed in Exp. II.

Temperatures during the middle periods in Exp. II were

negatively associated with temperature.

Generally temperature was negatively associated with seed size. The exception to this rule was the positive association of combinations of high initial and lower terminal temperatures in Exp. I with large seed size.

## Oil Content

One purpose of the present experiments was to determine the effect of several different temperature - time regimes on the quantity of oil synthesized in rapeseed. Experimental results presented in Tables V and VI show that temperature can have a marked effect on the physiological processes concerned with oil formation in rapeseed. This is illustrated by oil content data which ranged from 50.03% to 22.87% in Exp. I and from 46.74% to 27.09% in Exp. II.

### Experiment I

In Exp. I the temperature - time regime of variable temperature treatments was such that all plants were grown in the initial periods for a fixed duration of time, namely, an 11-day or 22-day period. The plants were then grown at the terminal temperature treatment until maturity. The oil contents of the rapeseed from the 15 temperature - time treatments are reported in Table V.

TABLE V Per cent oil of rapeseed from temperature - time treatments of Exp. I

| Treatment[1] / Degrees F. | X-X-55 | X-55-55 | X-X-70 | X-70-70 | X-X-85 | X-85-85 | Row mean |
|---|---|---|---|---|---|---|---|
| 55-55-X | 48.71 | | 40.28 | | 32.60 | | 40.53 |
| 55-X-X | | 48.71 | | 41.85 | | 22.87 | 37.81 |
| 70-70-X | 48.11 | | 41.24 | | 36.17 | | 41.84 |
| 70-X-X | | 49.42 | | 41.24 | | 27.73 | 39.46 |
| 85-85-X | 50.00 | | 41.37 | | 24.93 | | 38.76 |
| 85-X-X | | 50.03 | | 43.66 | | 24.93 | 39.54 |
| Column mean | 48.94 | 49.38 | 40.96 | 42.25 | 31.23 | 25.18 | |

1/ Treatments are coded as indicated in a three term expression X-X-X representing temperature treatments during initial and terminal periods. The middle term can be part of either initial or terminal period, depending on duration of initial period.

Constant Temperature Treatments

The per cent oil contents of rapeseed from the constant temperature treatments were:

| | |
|---|---|
| 55-55-55 | 48.71% |
| 70-70-70 | 41.24% |
| 85-85-85 | 24.93% |

It is evident that there was a marked decline in per cent oil as growing temperatures increased. The oil contents of the rapeseed from the 70-70-70 and 85-85-85 regimes were 84.6% and 51.2%, respectively, of that from the 55-55-55 regime (significant; $p = .05$). The higher the constant temperature at which the plants were grown, the greater the depressing effect on oil formation.

Variable Temperature Treatments

Results from variable temperature treatments show that variations in temperature during seed development can be associated with variations in oil content of rapeseed. These associations may be examined more specifically with relation to differences of temperatures between initial periods, between terminal periods, and between initial and terminal periods. In Exp. I the variable temperatures utilized were such that the temperature - time regimes involved only one temperature change per treatment, namely, a change in temperature following the end of 11-day or 22-day initial periods.

Plants were grown under temperature regimes wherein temperatures during 11-day initial periods were 55°F., 70° F. or 85° F. and were subsequently grown to maturity under 55° F. conditions. Oil contents were affected by these conditions:

| | |
|---|---|
| 55-55-55 | 48.71% |
| 70-55-55 | 49.42% |
| 85-55-55 | 50.03% |

The increased oil content obtained from the higher initial temperatures of 70° F., and 85° F., is significant ($p = .05$, Appendix C) but the increases obtained were not large. Under growing conditions where the temperature utilized during the long initial period was extended to include the middle period, the effects were somewhat similar:

| | |
|---|---|
| 55-55-55 | 48.71% |
| 70-70-55 | 48.11% |
| 85-85-55 | 50.00% |

The differences, while not large, are significant ($p = .05$ Appendix C). As previously stated in Materials and Methods, the time interval for the initial and middle period is only 11 days each. In contrast the terminal period is longer, being the time following the 22 day interval required for the plants to reach maturity. This means that the plants under any temperature - time regime are influenced by the terminal temperature for a longer period of time.

Other effects of higher temperature at particular times of plant development are illustrated by specific comparisons. Material kept for a 22-day initial period at $55^{\circ}$ F. and then grown under $70^{\circ}$ F., or $85^{\circ}$ F. terminal temperatures yielded seeds of lower oil content:

| | |
|---|---|
| 55-55-55 | 48.71% |
| 55-55-70 | 40.28% |
| 55-55-85 | 32.60% |

These differences in oil content are significant ($p = .05$ Appendix C) as are the following differences noted for other comparisons where a $70^{\circ}$ F. initial and $85^{\circ}$ F. terminal temperature was utilized:

| | |
|---|---|
| 70-70-70 | 41.24% |
| 70-70-85 | 36.17% |

When an 11-day initial period was followed by a higher temperature terminal period, the reduction in oil content was of a larger magnitude:

| | |
|---|---|
| 55-55-55 | 48.71% |
| 55-70-70 | 41.85% |
| 55-85-85 | 22.87% |

and:

| | |
|---|---|
| 70-70-70 | 41.24% |
| 70-85-85 | 27.73% |

A relatively cooler temperature during the 22-day initial periods generally resulted in higher oil content than resulted from treatment with 11-day initial periods of the same temperature.

When lower temperatures were applied to material which had begun development under 22-days of higher temperature conditions, the effects were opposite to those noted above. Some comparisons may be made among material which were similar for temperature conditions except for the terminal period:

| | |
|---|---|
| 85-85-85 | 24.93% |
| 85-85-70 | 41.37% |
| 85-85-55 | 50.00% |

and:

| | |
|---|---|
| 70-70-70 | 41.24% |
| 70-70-55 | 48.11% |

For both of these sets of comparisons, the increases in oil content were significant ($p = .05$ Appendix C) and extensive. This same effect was noted for material where higher temperatures were used during 11-day initial periods only:

| | |
|---|---|
| 85-85-85 | 24.93% |
| 85-70-70 | 43.66% |
| 85-55-55 | 50.03% |

and:

| | |
|---|---|
| 70-70-70 | 41.24% |
| 70-55-55 | 49.42% |

The influence of higher temperatures during the 11 day differential between short and long initial periods may be assessed

by cross-comparisons between the above four sets of data. A long initial period of higher temperature invariably resulted in a lower oil content than that observed for a short initial period of the same temperature. It will be noted that the difference in oil content is not large but is measurable in each specific appropriate comparison.

Experiment II

The results from Exp. II support those from the first experiment, that is, that the temperature to which the rape plants are exposed during their reproductive period of growth can have an effect on the physiological processes concerned with oil formation in rapeseed. The oil contents of the rapeseed from the 15 temperature - time treatments of Exp. II are reported in Table VI.

TABLE VI Per cent oil of rapeseed from 15 temperature - time treatments of Exp. II

| Treatments[1]/ Degrees F. | X-60-60 | 60-X-60 | X-70-70 | 70-X-70 | X-80-80 | 80-X-80 | Row mean |
|---|---|---|---|---|---|---|---|
| 60-X-X | 46.74 | | 41.03 | | 36.44 | | 41.40 |
| X-60-X | | 46.74 | | 41.43 | | 33.05 | 40.41 |
| 70-X-X | 45.40 | | 37.19 | | 34.00 | | 38.86 |
| X-70-X | | 44.64 | | 37.19 | | 30.58 | 37.47 |
| 80-X-X | 44.81 | | 37.92 | | 27.09 | | 36.60 |
| X-80-X | | 35.93 | | 37.47 | | 27.09 | 33.49 |
| Column mean | 45.65 | 42.44 | 38.71 | 38.69 | 32.51 | 30.24 | |

1/ Treatments are coded as indicated in a three term expression X-X-X representing temperature treatments during initial and terminal periods. The middle term can be part of either initial or terminal period, depending on duration of initial period.

Constant Temperature Treatments

The data reported in Table VI show the effect of three constant temperature treatments on the oil content of rapeseed. The effects on oil content were:

| | |
|---|---|
| 60-60-60 | 46.74% |
| 70-70-70 | 37.19% |
| 80-80-80 | 27.09% |

The temperature effects on oil content were inverse; the decrease in oil content with increase in temperature was significant in each instance ($p = .05$ Appendix D).

It is of interest to note that the oil content of rapeseed from 70-70-70 Exp. II was 3.05% lower than resulted from 70-70-70 Exp. I. This indicates that the higher fertility level of soil used in Exp. II resulted in a lower oil content.

Variable Temperature Treatments

The effects on oil content of variable temperature treatments are also reported in Table VI. These data give some indication as to the effect of temperature variation at a particular time during the reproductive processes of the rape.

The effects of higher middle and terminal temperatures are consistent with the fact reported previously for Exp. I that higher temperatures during reproductive development result in lowered oil contents. For material which flowered under 60° F. conditions and subsequently developed under higher temperatures the oil contents were:

| | |
|---|---|
| 60-60-60 | 46.74% |
| 60-70-70 | 41.03% |
| 60-80-80 | 36.44% |

Each of these variations of higher temperature after flowering resulted in a significant decrease in oil content ($p = .05$ Appendix D). The material which flowered under 70° F. conditions reacted somewhat similarly:

| | |
|---|---|
| 70-70-70 | 37.19% |
| 70-80-80 | 34.00% |

Raising the temperature for the period after flowering until maturity, significantly lowered the oil content ($p = .05$ Appendix D).

The effect of changes in temperature during only the 10 day period after flowering is illustrated by the following

data comparisons of oil contents:

| | |
|---|---|
| 70-70-70 | 37.19% |
| 70-60-70 | 41.43% |

A 10 degree lowering of temperature for a 10 day period after flowering, significantly raised the oil content ($p = .05$ Appendix D). A similar reaction was noted in the following comparisons:

| | |
|---|---|
| 80-80-80 | 27.09% |
| 80-70-80 | 30.58% |
| 80-60-80 | 33.05% |

Each increase in oil content above that recorded for the 80-80-80 constant temperature treatment was significant and the effect is attributable to a lowering of temperature for only the 10 day period following the end of flowering at which time the initial temperature was restored. This is substantiated by the comparisons of the oil contents of:

| | |
|---|---|
| 60-80-60 | 35.93% |
| 60-70-60 | 44.64% |
| 60-60-60 | 46.74% |

These differences are significant ($p = .05$ Appendix D) but no significant differences were found when the growing enviroments were:

| | |
|---|---|
| 70-80-70 | 37.47% |
| 70-70-70 | 37.19% |

In this comparison, only, the change of temperature for the 10 day period after flowering, did not raise the oil content.

When the temperature was lowered at the end of the flowering period and maintained until maturity, at the lower level, the effect was to increase the oil content further. This is clearly evident in the comparisons of oil contents

of:

| | |
|---|---|
| 80-60-80 | 33.05% |
| 80-60-60 | 44.81% |

and:

| | |
|---|---|
| 80-70-80 | 30.58% |
| 80-70-70 | 37.92% |

and:

| | |
|---|---|
| 70-60-70 | 41.43% |
| 70-60-60 | 45.40% |

These differences in oil content are significant ($p = .05$ Appendix D). It will be noted that the sizes of the increases in oil content are greather than those observed for material where the temperatures were lowered for the 10 day period only.

The results of the various comparisons of oil yields derived under growing conditions utilized in Exp. II show that increase of temperature for any period was strongly associated with a decrease in oil content of rapeseed. Elevated temperatures during terminal periods occasioned an approximate five-fold greater reduction in per cent oil than did the same temperatures during initial periods. Decreased temperatures during initial periods resulted in appreciably higher per cent oil content than was obtained from rapeseed that developed under an appropriate constant higher temperature. Decreased temperatures during the 10 day middle period were associated with an increase in oil content. Even a period as short as 10 days after flowering is influential in determining oil content. Continued exposure of plants to a decreased temperature until maturity increased oil contents still further.

Summary

Results from constant temperature treatments of both experiments show that increasing temperature was associated with decreasing per cent oil contents of rapeseed. Similarly, results from variable temperature treatments of both experiments show that increased temperatures of terminal periods of treatments were associated with lowered oil contents of rapeseed.

Increased temperatures during initial periods of variable temperature treatments from Exp. I tended to increase per cent oil content of rapeseed. In contrast, increased temperatures during initial periods of variable temperature treatments from Exp. II generally resulted in a slight decrease in oil content. These contrasting results suggest that the role of elevated temperatures changes during as the seed progressively develops.

Elevated temperatures during the 10 day middle period of three-part treatments from Exp. II generally resulted in reduced oil contents, whereas, decreased temperatures during the middle periods invariably resulted in higher oil contents.

There is some evidence that high soil fertility results in a lower oil content.

## Iodine Number

Iodine number is a measure of total unsaturation of a fat or oil and is defined as the number of grams of iodine absorbed by 100 grams of fat. The degree of unsaturation of rapeseed oil was influenced by temperatures in which plants were grown from bolting to maturity. Iodine values for Exp. I ranged from 83.4 to 102.0 and for Exp. II from 83.1 to 101.2 These ranges demonstrate that temperature is a major factor in determining the degree of unsaturation of rapeseed oil.

### Experiment I

#### Constant Temperature Treatments

There was a strong negative association between iodine number of the oil and temperature when a constant temperature was maintained from bolting to maturity. The negative association is illustrated by:

| | |
|---|---|
| 55-55-55 | 99.7 |
| 70-70-70 | 95.9 |
| 85-85-85 | 94.4 |

TABLE VII Iodine numbers of rapeseed oil from temperature - time treatments of Exp. I

| Treatment[1/] Degrees F. | X-X-55 | X-55-55 | X-X-70 | X-70-70 | X-X-85 | X-85-85 | Row mean |
|---|---|---|---|---|---|---|---|
| 55-55-X | 99.7 | | 94.8 | | 83.4 | | 92.6 |
| 55-X-X | | 99.7 | | 94.9 | | 87.9 | 94.2 |
| 70-70-X | 102.0 | | 95.9 | | 86.5 | | 94.6 |
| 70-X-X | | 101.4 | | 95.9 | | 90.9 | 96.1 |
| 85-85-X | 102.0 | | 98.1 | | 94.4 | | 98.1 |
| 85-X-X | | 98.7 | | 96.1 | | 94.4 | 96.4 |
| Column mean | 101.2 | 99.9 | 96.3 | 95.6 | 88.1 | 91.0 | |

1/ Treatments are coded as indicated in a three term expression X-X-X representing temperature treatment during initial and terminal periods. The middle term can be part of either initial or terminal period, depending on duration of initial period.

Variable Temperature Treatments

Experimental results presented in Table VII provide evidence of a positive association between temperature of initial periods of treatments and iodine number of rapeseed oil. This may be illustrated by two series of comparisons. The first series involves treatments in which the temperature of initial periods was the same or higher than that of terminal periods. For example:

| | |
|---|---|
| 55-55-55 | 99.7 |
| 70-70-55 | 102.0 |
| 85-85-55 | 102.0 |

and:

| | |
|---|---|
| 70-70-70 | 95.9 |
| 85-85-70 | 98.1 |

The other series includes treatments in which the temperature

of initial periods was the same or lower than that of terminal periods:

| | |
|---|---|
| 85-85-85 | 94.4 |
| 70-70-85 | 86.5 |
| 55-55-85 | 83.4 |

and:

| | |
|---|---|
| 70-70-70 | 95.9 |
| 55-55-70 | 94.8 |

The above comparisons concern the positive association between temperature of 22-day initial periods and iodine number only, but further consideration of data in Table VII will show that a similar relationship existed for 11-day initial periods.

The negative association of terminal period temperature with iodine number may be examined by making two series of comparisons similar to those used for illustrating initial period temperature effects. The first series:

| | |
|---|---|
| 55-55-55 | 99.7 |
| 55-55-70 | 94.8 |
| 55-55-85 | 83.4 |

and:

| | |
|---|---|
| 70-70-70 | 95.9 |
| 70-70-85 | 86.5 |

These data show that a strong negative association existed between terminal period temperature and iodine number. This is verified by the other series of comparisons:

| | |
|---|---|
| 85-85-85 | 94.4 |
| 85-85-70 | 98.1 |
| 85-85-55 | 102.0 |

and:

| | |
|---|---|
| 70-70-70 | 95.9 |
| 70-70-55 | 102.0 |

The degree of effect on iodine number by interaction of initial and terminal temperature may be demonstrated by

ranges of iodine numbers derived from data that was grouped according to temperature and by time periods. The ranges are as follows:

| | Ranges by periods | |
|---|---|---|
| | initial | terminal |
| 85°F. | 7.6 | 11.0 |
| 70°F. | 15.5 | 3.3 |
| 55°F. | 16.3 | 3.3 |

The large ranges for 55°F., and 70° F. initial periods may be attributed to strong interactions of these initial temperatures with 85°F. terminal periods. This is substantiated by the relatively large range recorded for 85° F. terminal periods. The narrow ranges for 55° F., and 70° F. terminal periods indicate that these terminal temperatures were more effective than initial temperatures in modifying iodine number.

In general, the experimental results indicate that the association of iodine number with initial temperatures was positive, but was negative with terminal temperature; and that the effect of any particular temperature appears to have been modified to a greater or lesser degree by the temperature that preceded or followed it.

## Experiment II

### Constant Temperature Treatments

There was a pronounced negative association between iodine number and temperature as shown by:

| | |
|---|---|
| 60-60-60 | 99.7 |
| 70-70-70 | 97.5 |
| 80-80-80 | 87.9 |

The differences between iodine number were significant ($p = .05$ Appendix F) and confirm the results obtained from Exp. I.

TABLE VIII Iodine Numbers of rapeseed oil from temperature - time treatments of Exp. II

| Treatment[1]/ Degrees F. | X-60-60 | 60-X-60 | X-70-70 | 70-X-70 | X-80-80 | 80-X-80 | Row mean |
|---|---|---|---|---|---|---|---|
| 60-X-X | 99.7 | | 90.8 | | 88.6 | | 91.4 |
| X-60-X | | 99.7 | | 97.0 | | 90.2 | 95.6 |
| 70-X-X | 101.2 | | 97.5 | | 83.1 | | 93.9 |
| X-70-X | | 95.3 | | 97.5 | | 89.8 | 94.2 |
| 80-X-X | 101.0 | | 91.3 | | 87.9 | | 93.4 |
| X-80-X | | 86.7 | | 86.7 | | 87.9 | 87.1 |
| Column mean | 100.6 | 93.9 | 93.2 | 93.7 | 84.9 | 89.3 | |

1/ Treatments have been coded as indicated by a three term expression X-X-X representing temperature treatments during initial, middle and terminal periods respectively.

Variable Temperature Treatments

The comparatively weak positive association between initial period temperature and iodine number may be demonstrated by two series of comparisons. The first series involves treatments in which the temperature of initial periods was the same or higher than that of terminal periods. Results from these treatments were:

| | |
|---|---|
| 60-60-60 | 99.7 |
| 70-60-60 | 101.2 |
| 80-60-60 | 101.0 |

and:

| | |
|---|---|
| 70-70-70 | 97.5 |
| 80-70-70 | 91.3 |

The other series included treatments in which the temperature of initial periods was the same or lower than that of terminal periods. Results from these treatments were:

| | |
|---|---|
| 80-80-80 | 87.9 |
| 70-80-80 | 83.1 |
| 60-80-80 | 83.6 |

There was a strong and consistent negative association between iodine numbers and terminal temperatures. This is illustrated below by two series of comparisons similar to those used to show the effect of initial temperatures. The first series of comparisons are:

| | |
|---|---|
| 60-60-60 | 99.7 |
| 60-70-70 | 90.8 |
| 60-80-80 | 83.6 |

and:

| | |
|---|---|
| 70-70-70 | 97.5 |
| 70-80-80 | 83.1 |

The other series verifies the first:

| | |
|---|---|
| 80-80-80 | 87.9 |
| 80-70-70 | 91.3 |
| 80-60-60 | 101.0 |

and:

| | |
|---|---|
| 70-70-70 | 97.5 |
| 70-60-60 | 101.2 |

Temperatures of the 10 day middle period were negatively associated with iodine numbers. This is shown by the following data:

| | |
|---|---|
| 60-60-60 | 99.7 |
| 60-70-60 | 95.3 |
| 60-80-60 | 86.7 |

and:

| | |
|---|---|
| 70-70-70 | 97.5 |
| 70-80-70 | 86.7 |

The negative association is substantiated by:

| | |
|---|---|
| 80-80-80 | 87.9 |
| 80-70-80 | 89.8 |
| 80-60-80 | 90.2 |

Thus even a 10 day period of higher temperature immediately following end of flowering can result in a sharp decline in iodine number. Iodine numbers were lowered still further by exposing plants to elevated temperatures from end of flowering till maturity. This is illustrated by:

| | |
|---|---|
| 60-70-60 | 95.3 |
| 60-70-70 | 90.8 |
| 60-80-60 | 86.7 |
| 60-80-80 | 83.6 |
| 70-80-70 | 86.7 |
| 70-80-80 | 83.1 |

Evidently the effect of higher temperatures on iodine number continued beyond the 10 day middle period. It should be noted that the greatest lowering of iodine numbers as a result of 80° F. temperature occurred during the 10 day period immediately following flowering.

Lowered temperatures during the 10 day middle period were positively associated with iodine numbers as shown by:

| | |
|---|---|
| 80-80-80 | 87.9 |
| 80-70-80 | 89.8 |
| 80-60-80 | 90.2 |

and:

| | |
|---|---|
| 70-70-70 | 97.5 |
| 70-60-70 | 97.0 |

Material kept at a lower temperature after the end of the 10 day middle period had a considerably higher iodine number as shown by:

| | |
|---|---|
| 80-60-80 | 90.2 |
| 80-60-60 | 101.0 |

and:

| | |
|---|---|
| 80-70-80 | 89.8 |
| 80-70-70 | 91.3 |

and:

| | |
|---|---|
| 70-60-70 | 97.0 |
| 70-60-60 | 101.2 |

The relative effects of time periods and temperatures on iodine number may be studied by examining the ranges of iodine numbers for time periods and for temperatures. These ranges were:

| | Ranges by periods | | |
|---|---|---|---|
| | initial | middle | terminal |
| 60° F. | 16.1 | 9.5 | 1.5 |
| 70° F. | 18.1 | 6.7 | 6.7 |
| 80° F. | 13.1 | 1.2 | 4.6 |

The large ranges for initial periods and the small ranges for terminal periods indicate that terminal temperatures had the greater effect on iodine number. The extremely small range for 80° F. middle periods indicates that this temperature exerted its greatest influence on iodine number during these periods.

It is of interest that the difference between iodine numbers resulting from 70-70-70 Exp. I, and 70-70-70 Exp. II, was only 1.6 units even though the equivalent of 2250 pounds of fertilizer per acre was added to soil used for Exp. II.

A "t" test, as described by Snedecor (16), of non processed data (Appendice I and J) showed that the difference between these iodine numbers was non significant ($p = 0.3$). If the level of soil fertility did not influence iodine number then it is remarkable that the iodine number from 85-85-85 Exp. I was about 7 units higher than was obtained from 80-80-80 Exp. II.

Summary

There was a high negative association between temperature and iodine number of rapeseed oil developed under constant temperature regimes of both experiments.

Temperature of initial periods of both experiments was positively associated with iodine number.

A strong negative association was evident between temperature of terminal periods and iodine number of both experiments. Temperature of the 10 day middle period of Exp. II was negatively associated with iodine number.

## Protein Content

Protein content of the seed produced under temperature - time treatments was determined in order to relate the treatment influences with possible variations in protein content. Data on per cent protein presented in Tables IX and X, below, show that the range of protein contents in Exp. I was 12.4% and, in Exp. II was 11.4%. These relatively large ranges indicate that treatments markedly affected per cent protein of rapeseed meal.

### Experiment I

#### Constant Temperature Treatments

Data in Table IX show the effects of constant temperature treatments on protein content. These were:

| | |
|---|---|
| 55-55-55 | 34.5% |
| 70-70-70 | 40.6% |
| 85-85-85 | 40.5% |

Protein content from seed raised under low temperature conditions of the experiment was about 6% lower than that obtained from seed grown under the intermediate and high temperature conditions. Seed grown under 70° F. and 85° F. conditions had a significantly ($p = .05$ Appendix H) higher protein content than that grown under 55° F.

TABLE IX Per cent protein of rapeseed meal from temperature - time treatments of Exp. I

| Treatment[1/] Degrees F. | X-X-55 | X-55-55 | X-X-70 | X-70-70 | X-X-85 | X-85-85 | Row mean |
|---|---|---|---|---|---|---|---|
| 55-55-X | 34.5 | | 41.2 | | 47.3 | | 41.0 |
| 55-X-X | | 34.5 | | 40.3 | | 40.9 | 38.6 |
| 70-70-X | 38.8 | | 40.6 | | 42.7 | | 40.7 |
| 70-X-X | | 37.1 | | 40.6 | | 42.6 | 40.1 |
| 85-85-X | 34.8 | | 41.9 | | 40.5 | | 39.1 |
| 85-X-X | | 36.2 | | 39.1 | | 40.5 | 38.6 |
| Column mean | 36.0 | 35.9 | 41.2 | 40.0 | 43.5 | 41.3 | |

1/ Treatments have been coded as indicated by a three term expression X-X-X representing temperature treatment during initial and terminal periods. The middle term may be part of either initial or terminal period, depending on duration of initial period.

Variable Temperature Treatments

Associations between protein content of rapeseed meal and initial period temperature are evident from data in Table IX. There were no consistent trends of association between initial period temperatures and protein content. This is shown by the comparisons:

| | |
|---|---|
| 55-55-55 | 34.5% |
| 70-55-55 | 37.1% |
| 85-55-55 | 36.2% |

and:

| | |
|---|---|
| 70-70-70 | 40.6% |
| 85-70-70 | 39.1% |

These comparisons show that changes in initial period temperatures did not affect protein content. Similarly, protein content was not affected by temperature during 22-day initial

periods, and is illustrated by the following comparisons:

| | |
|---|---|
| 55-55-55 | 34.5% |
| 70-70-55 | 38.8% |
| 85-85-55 | 34.8% |

and:

| | |
|---|---|
| 70-70-70 | 40.6% |
| 85-85-70 | 41.9% |

There is some evidence in the data of Table IX that increases in temperature during the terminal periods do have an effect in raising the protein content for material which had an 11-day initial period of 55° F. The effect on the material was:

| | |
|---|---|
| 55-55-55 | 34.5% |
| 55-70-70 | 40.3% |
| 55-85-55 | 40.9% |

The 70° F. initial temperature material reacted similarly but the increase in protein content was not as great.

| | |
|---|---|
| 70-70-70 | 40.6% |
| 70-85-85 | 42.6% |

The greatest effect of increased temperatures was observed for material which had begun development under 22-day initial period at 55° F. and then ripened under higher temperatures:

| | |
|---|---|
| 55-55-55 | 34.5% |
| 55-55-70 | 41.2% |
| 55-55-85 | 47.3% |

A similar trend is shown for the 70° F. material but the effect was much lower.

| | |
|---|---|
| 70-70-70 | 40.6% |
| 70-70-85 | 42.7% |

The effects of decreasing the temperatures during the growth periods of Exp. I are shown by such comparisons as:

| | |
|---|---|
| 85-85-85 | 40.5% |
| 85-85-70 | 41.9% |
| 85-85-55 | 34.8% |

The cooler temperature, 55° F., during the terminal period significantly reduced the protein content ($p = .05$ Appendix G). A similar but less marked reduction in protein content was noted for the 70° F. material.

| | |
|---|---|
| 70-70-70 | 40.6% |
| 70-70-55 | 38.8% |

For treatments in which an 11-day initial period of higher temperature was followed by a terminal period of cooler temperature also resulted in lowered protein content but the reductions were somewhat smaller.

| | |
|---|---|
| 85-85-85 | 40.5% |
| 85-70-70 | 39.1% |
| 85-55-55 | 36.2% |

and:

| | |
|---|---|
| 70-70-70 | 40.6% |
| 70-55-55 | 37.1% |

Under the conditions of Exp. I, the rapeseed meal produced under the constant temperature of 55° F. was significantly lower in protein content. Variations in temperature during the experimental period resulted in some variations in protein content as noted. The most pronounced effect noted was that high terminal temperatures were associated with high protein contents.

Experiment II

Protein content of rapeseed meal produced under growing conditions of Exp. II provides further information on the

effect of temperature changes during the period of growth and maturation of rape. These data are reported in Table X. It will be noted that no protein content data were available for the 60-60-60 time - temperature regime. This negates the possibility of some comparisons.

TABLE X Per cent protein of rapeseed from temperature - time treatments of Exp. II

| Treatments[1/] Degrees F. | X-60-60 | 60-X-60 | X-70-70 | 70-X-70 | X-80-80 | 80-X-80 | Row mean |
|---|---|---|---|---|---|---|---|
| 60-X-X | | | 41.8 | | 43.6 | | 42.7 |
| X-60-X | | | | 42.9 | | 45.6 | 44.2 |
| 70-X-X | 39.1 | | 44.2 | | 44.3 | | 42.5 |
| X-70-X | | 38.0 | | 44.2 | | 45.2 | 42.5 |
| 80-X-X | 36.7 | | 46.2 | | 47.9 | | 43.6 |
| X-80-X | | 44.3 | | 44.5 | | 47.9 | 45.6 |
| Column mean | 37.9 | 41.1 | 44.1 | 43.9 | 45.3 | 46.2 | |

1/ Treatments have been coded as indicated by a three term expression X-X-X representing temperature treatment during initial, middle and terminal periods respectively.

Constant Temperature Treatments

Available comparisons of protein content of rapeseed meal produced under constant temperature growing conditions show:

| | |
|---|---|
| 70-70-70 | 44.2% |
| 80-80-80 | 47.9% |

Per cent protein of rapeseed meal from 80-80-80 treatment was the highest obtained in Exp. II. High per cent protein

content is associated with high uniform temperature.

Variable Temperature Treatments

Protein content of variable temperature regimes are reported in Table X. Increased initial period temperatures were associated with higher protein contents with some exceptions as noted in comparisons of:

| | |
|---|---|
| 60-60-60 | no data |
| 70-60-60 | 39.1% |
| 80-60-60 | 36.7% |

where there was a drop in protein content and

| | |
|---|---|
| 70-70-70 | 44.2% |
| 80-70-70 | 46.2% |

where there was an increase in protein content.

Effect of temperature during initial period can be further assessed by the following comparisons:

| | |
|---|---|
| 80-80-80 | 47.9% |
| 70-80-80 | 44.3% |
| 60-80-80 | 43.6% |

and:

| | |
|---|---|
| 70-70-70 | 44.2% |
| 60-70-70 | 41.8% |

As noted under the discussion about constant temperature treatments, material raised under high temperatures had the highest protein content. Lowering the temperature during the period of growth up to the end of flowering, depressed the protein content.

The effect of terminal temperatures may be assessed from the data contained in Table X for column means. The average effects of terminal temperatures on protein content

were:

| | |
|---|---|
| X-60-60 | 37.9 |
| X-70-70 | 44.1 |
| X-80-80 | 45.3 |

The trend is evident that high temperature during seed development and maturation is associated with high protein content.

The effect of changes in temperature during the 10 day period after flowering are of interest as well. When temperature was lowered for this 10 day period, the protein contents were generally lowered significantly ($p = .05$ Appendix H), as evidenced by:

| | |
|---|---|
| 80-80-80 | 47.9% |
| 80-70-80 | 45.2% |

and:

| | |
|---|---|
| 70-70-70 | 44.2% |
| 70-60-70 | 42.9% |

Reduction in temperature during the middle period, however, was not always accompanied by a lowering of protein content as shown by:

| | |
|---|---|
| 80-70-80 | 45.2% |
| 80-60-80 | 45.6% |

and:

| | |
|---|---|
| 70-80-70 | 44.5% |
| 70-70-70 | 44.2% |

These changes are non significant ($p = .05$ Appendix H) but serve to indicate that the actual changes in temperature during the middle period cannot be considered independent of the temperatures employed during the initial and terminal periods.

Effect of higher temperatures during terminal periods is illustrated by comparisons of:

| | |
|---|---|
| 60-70-70 | 41.8% |
| 60-80-80 | 43.6% |

and:

| | |
|---|---|
| 70-70-70 | 44.2% |
| 70-80-80 | 44.3% |

In each comparison there is evidenced an increase in protein content accompanying an increase in temperature. The effect is less pronounced for material which had already been growing at 70° F., compared to that at 60° F. Once again, as indicated above, the magnitude of the change in protein content is related to the temperature under which the material had been growing in the previous period.

Exp. II results show that high temperature was generally associated with higher protein content. The data in Table X show that the seven highest protein contents were all associated with treatments involving 80° F. during one or more time periods. The data also indicate that the lower protein contents reported are associated with one or more time periods at 60° F.

Summary

Results from constant temperature treatments from both experiments show that higher temperature was associated with higher protein content of rapeseed meal.

In Exp. II, treatments that had cool initial temperatures

followed by 85° F. terminal periods resulted in higher protein content as evidenced by:

| | |
|---|---|
| 55-55-85 | 47.3% |
| 85-85-85 | 40.5% |

whereas, in Exp. II the highest protein content was:

| | |
|---|---|
| 80-80-80 | 47.9% |
| 80-60-80 | 45.6% |

These results seem to be at variance with respect to the effects of early temperatures. Under the conditions of Exp. I, however, the initial period was 22 days in duration. In Exp. II, the same period was 45 days for material at 70° F. and was 50 days for material at 60° F. In effect, in both experiments, the high protein contents resulted from treatments with long exposure to high temperature.

## Correlations

Results from the two experiments show that seed size, oil content, iodine number of the oil, and protein content of rapeseed are to some degree dependent on the temperatures prevailing during seed development. Consequently, correlation coefficients were calculated according to the method outlined by Snedecor (16) to measure the mutual variation of treatment means for these seed characteristics.

TABLE XI Correlation coefficients for Experiments I and II

| | | Protein Content | Iodine Number | Oil Content | Seed Size |
|---|---|---|---|---|---|
| Days - start flowering to maturity | Exp. II | -.69** | .80** | .69** | .68** |
| Seed size | Exp. I | -.65** | .71** | .95** | |
| | Exp. II | -.65* | .62* | .88** | |
| Oil content | Exp. I | -.69** | .77** | | |
| | Exp. II | -.85** | .70** | | |
| Iodine number | Exp. I | -.84** | | | |
| | Exp. II | -.65** | | | |

** Significant at p = .01
* Significant at p = .05

Correlation coefficients presented in Table XI show that in both experiments protein content was negatively correlated with all the other seed characteristics. Seed size, oil content and iodine number were positively correlated to one another.

In both experiments the highest coefficients (.95 and .88) occurred for the correlation between seed size and oil content. These strong positive correlations suggest that within a uniform variety seed size could perhaps be used by grain buyers for estimating the oil content of rapeseed.

Experimental results presented in preceding sections indicate that temperature had a direct effect on the seed characteristics under study. However, the highly significant ($p = .01$) coefficients (Table XI) for the correlation between the number of days required from start of flowering to maturity with seed size, oil content, iodine number, and protein content suggests that temperature may have affected these seed characteristics indirectly by limiting the time available for the metabolic processes concerning oil and protein formation in rapeseed.

## GENERAL SUMMARY

In two experiments Golden rape was grown from beginning of bolting until maturity in controlled temperature growth chambers. The purpose of both experiments was to determine the effects of various temperature - time regimes on seed size (100 K weight), oil content, iodine number of the oil, and protein content of rapeseed.

Temperatures of constant temperature treatments of both experiments were negatively associated with seed size, oil content, and iodine number, but were positively associated with protein content.

In Exp. I temperatures during initial periods of variable temperature treatments were generally weakly but positively associated with seed size, oil content, and iodine number. Conversely, in Exp. II there was a tendency for a weak negative association between initial temperatures and seed size, and oil content, but there was some evidence of a positive association between initial temperature and iodine number. The generally opposite effects of initial temperatures between the two experiments perhaps was due to the difference in length of initial periods. The longer initial period in Exp. I was an arbitrary 22 days, whereas in Exp. II the duration of the initial periods was governed by the time required for the plants to complete flowering which varied from 40 days ($80^{\circ}$ F.) to 50 days ($60^{\circ}$ F.). Perhaps the role

of high temperature in its effect on seed size, oil content, and iodine number may have been reversed as the rapeseed developed and this reversal may have occurred at approximately the end of flowering.

In both experiments there was a strong negative association between temperatures of terminal periods and seed size, oil content, and iodine number.

Protein contents from both experiments were positively associated with terminal temperatures but were relatively unaffected by initial temperatures.

Protein content was negatively correlated with seed size, oil content, iodine number and number of days from early flowering to maturity.

There was a mutual and positive correlation between seed size, oil content, iodine number, and the number of days from early flowering to maturity.

The highest correlation coefficient in each experiment occurred for the covariation of seed size and oil content. It was suggested that these high correlation coefficients (.95 and .88) indicate that within a uniform variety seed size may be used for estimating the oil content of rapeseed.

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# APPENDICES

APPENDIX A Differences in 100-seed weight between means of treatments in Exp. I

| Treatment | | Differences between treatment means (100 seed weight in grams) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No.[1] | Mean | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 |
| 1 | .4195 | .2786 | .2688 | .2471 | .2016 | .1320 | .1217 | .1209 | .1057 | .0984 | .0790 | .0789 | .0510 | .0457 | .0053[2] |
| 2 | .4142 | .2733 | .2635 | .2418 | .1963 | .1267 | .1164 | .1156 | .1004 | .0931 | .0737 | .0736 | .0457 | .0404 | |
| 3 | .3738 | .2329 | .2231 | .2014 | .1559 | .0863 | .0760 | .0752 | .0600 | .0527 | .0333 | .0332 | .0053[2] | | |
| 4 | .3685 | .2276 | .2178 | .1961 | .1506 | .0810 | .0707 | .0699 | .0547 | .0474 | .0280 | .0279 | | | |
| 5 | .3406 | .1997 | .1899 | .1682 | .1227 | .0531 | .0428 | .0420 | .0268 | .0195 | .0001[2] | | | | |
| 6 | .3405 | .1996 | .1898 | .1681 | .1226 | .0530 | .0427 | .0419 | .0267 | .0194 | | | | | |
| 7 | .3201 | .1802 | .1704 | .1487 | .1032 | .0336 | .0233 | .0225 | .0073 | | | | | | |
| 8 | .3138 | .1729 | .1631 | .1414 | .0959 | .0263 | .0160 | .0152 | | | | | | | |
| 9 | .2986 | .1577 | .1479 | .1262 | .0807 | .0111 | .0008[2] | | | | | | | | |
| 10 | .2978 | .1569 | .1471 | .1254 | .0799 | .0103 | | | | | | | | | |
| 11 | .2875 | .1466 | .1368 | .1151 | .0696 | | | | | | | | | | |
| 12 | .2179 | .0770 | .0672 | .0455 | | | | | | | | | | | |
| 13 | .1724 | .0315 | .0217 | | | | | | | | | | | | |
| 14 | .1507 | .0098 | | | | | | | | | | | | | |
| 15 | .1409 | | | | | | | | | | | | | | |

1

| No. | Temperature | No. | Temperature | No. | Temperature |
|---|---|---|---|---|---|
| 1 | 85-85-55 | 6 | 55-55-55 | 11 | 55-70-70 |
| 2 | 85-55-55 | 7 | 85-70-70 | 12 | 55-55-85 |
| 3 | 70-70-55 | 8 | 70-70-85 | 13 | 85-85-85 |
| 4 | 70-55-55 | 9 | 55-55-70 | 14 | 70-85-85 |
| 5 | 85-85-70 | 10 | 70-70-70 | 15 | 55-85-85 |

2 These differences are not significant. All other differences are significant (p = .05)

APPENDIX B Differences in 100-seed weight between means of treatments in Exp. II

| Treatment No.[1] | Mean | Differences between treatment means (100 seed weight in grams) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 |
| 1 | .3434 | .1219 | .1142 | .0782 | .0742 | .0712 | .0579 | .0493 | .0374 | .0271 | .0207 | .0101[2] | .0091[2] | .0058[2] | .0015[2] |
| 2 | .3419 | .1204 | .1127 | .0767 | .0727 | .0697 | .0564 | .0478 | .0359 | .0256 | .0192 | .0086[2] | .0076[2] | .0043[2] | |
| 3 | .3376 | .1161 | .1084 | .0724 | .0684 | .0654 | .0521 | .0435 | .0316 | .0213 | .0149 | .0043[2] | .0033[2] | | |
| 4 | .3343 | .1128 | .1051 | .0691 | .0651 | .0621 | .0488 | .0402 | .0283 | .0180 | .0116 | .0010[2] | | | |
| 5 | .3333 | .1118 | .1041 | .0681 | .0641 | .0611 | .0478 | .0392 | .0273 | .0170 | .0106 | | | | |
| 6 | .3227 | .1012 | .0935 | .0575 | .0535 | .0505 | .0372 | .0286 | .0167 | .0064[2] | | | | | |
| 7 | .3163 | .0948 | .0871 | .0511 | .0471 | .0441 | .0308 | .0222 | .0103 | | | | | | |
| 8 | .3060 | .0845 | .0768 | .0408 | .0368 | .0338 | .0205 | .0119 | | | | | | | |
| 9 | .2941 | .0726 | .0649 | .0289 | .0249 | .0219 | .0086[2] | | | | | | | | |
| 10 | .2855 | .0640 | .0563 | .0203 | .0163 | .0133 | | | | | | | | | |
| 11 | .2722 | .0507 | .0430 | .0070[2] | .0030[2] | | | | | | | | | | |
| 12 | .2692 | .0477 | .0400 | .0040[2] | | | | | | | | | | | |
| 13 | .2652 | .0437 | .0360 | | | | | | | | | | | | |
| 14 | .2292 | .0077[2] | | | | | | | | | | | | | |
| 15 | .2215 | | | | | | | | | | | | | | |

1

| No. | Temperature | No. | Temperature | No. | Temperature |
|---|---|---|---|---|---|
| 1 | 60-70-60 | 6 | 70-60-60 | 11 | 70-80-70 |
| 2 | 60-70-70 | 7 | 70-60-70 | 12 | 60-80-80 |
| 3 | 60-60-60 | 8 | 70-70-70 | 13 | 80-60-80 |
| 4 | 80-70-70 | 9 | 60-80-60 | 14 | 80-80-80 |
| 5 | 80-60-60 | 10 | 70-80-80 | 15 | 80-70-80 |

2 These differences are not significant. All other differences are significant ($p = .05$)

APPENDIX C Differences in per cent oil content between means of treatments in Exp. I

| Treatment | | Differences between treatment means (per cent oil) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No.[1] | Mean | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 |
| 1 | 50.03 | 27.16 | 25.10 | 22.30 | 17.43 | 13.86 | 9.75 | 8.79 | 8.66 | 8.18 | 6.37 | 1.92 | 1.32 | 0.61[2] | 0.03[2] |
| 2 | 50.00 | 27.13 | 25.07 | 22.27 | 17.40 | 13.83 | 9.72 | 8.76 | 8.63 | 8.15 | 6.34 | 1.89 | 1.29 | 0.58 | |
| 3 | 49.42 | 26.55 | 24.49 | 21.69 | 16.82 | 13.25 | 9.14 | 8.18 | 8.05 | 7.57 | 5.76 | 1.31 | 0.71 | | |
| 4 | 48.71 | 25.84 | 23.78 | 20.98 | 16.11 | 12.54 | 8.43 | 7.47 | 7.34 | 6.86 | 5.05 | 0.60 | | | |
| 5 | 48.11 | 25.24 | 23.18 | 20.38 | 15.51 | 11.94 | 7.83 | 6.87 | 6.74 | 6.26 | 4.45 | | | | |
| 6 | 43.66 | 20.79 | 18.73 | 15.93 | 11.06 | 7.49 | 3.38 | 2.42 | 2.29 | 1.81 | | | | | |
| 7 | 41.85 | 18.98 | 16.92 | 14.12 | 9.25 | 5.68 | 1.57 | 0.61[2] | 0.48[2] | | | | | | |
| 8 | 41.37 | 18.50 | 16.44 | 13.64 | 8.77 | 5.20 | 1.09 | 0.13[2] | | | | | | | |
| 9 | 41.24 | 18.37 | 16.31 | 13.51 | 8.64 | 5.07 | 0.96 | | | | | | | | |
| 10 | 40.28 | 17.41 | 15.35 | 12.55 | 7.68 | 4.11 | | | | | | | | | |
| 11 | 36.17 | 13.30 | 11.24 | 8.44 | 3.57 | | | | | | | | | | |
| 12 | 32.60 | 9.73 | 7.67 | 4.87 | | | | | | | | | | | |
| 13 | 27.73 | 4.86 | 2.80 | | | | | | | | | | | | |
| 14 | 24.93 | 2.06 | | | | | | | | | | | | | |
| 15 | 22.87 | | | | | | | | | | | | | | |

1

| No. | Treatment | No. | Treatment | No. | Treatment |
|---|---|---|---|---|---|
| 1 | 85-55-55 | 6 | 85-70-70 | 11 | 70-70-85 |
| 2 | 85-85-55 | 7 | 55-70-70 | 12 | 55-55-85 |
| 3 | 70-55-55 | 8 | 85-85-70 | 13 | 70-85-85 |
| 4 | 55-55-55 | 9 | 70-70-70 | 14 | 85-85-85 |
| 5 | 70-70-55 | 10 | 55-55-70 | 15 | 55-85-85 |

2 These differences are not significant. All other differences are significant ($p = .05$)

APPENDIX D Differences in per cent oil content between means of treatments in Exp. II

| Treatment | | Differences between treatment means (per cent oil) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No.[1] | Mean | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 |
| 1 | 46.74 | 19.65 | 16.16 | 13.69 | 12.74 | 10.81 | 10.30 | 9.55 | 9.27 | 8.82 | 5.71 | 5.31 | 2.10 | 1.93 | 1.34 |
| 2 | 45.40 | 18.31 | 14.82 | 12.35 | 11.40 | 9.47 | 8.96 | 8.21 | 7.93 | 7.48 | 4.37 | 3.97 | 0.76[2] | 0.59[2] | |
| 3 | 44.81 | 17.72 | 14.23 | 11.76 | 10.81 | 8.88 | 8.37 | 7.62 | 7.34 | 6.89 | 3.78 | 3.38 | 0.17[2] | | |
| 4 | 44.64 | 17.55 | 14.06 | 11.59 | 10.64 | 8.71 | 8.20 | 7.45 | 7.17 | 6.72 | 3.61 | 3.21 | | | |
| 5 | 41.43 | 14.34 | 10.85 | 8.38 | 7.43 | 5.50 | 4.99 | 4.24 | 3.96 | 3.51 | 0.40[2] | | | | |
| 6 | 41.03 | 13.94 | 10.45 | 7.98 | 7.03 | 5.10 | 4.59 | 3.84 | 3.56 | 3.11 | | | | | |
| 7 | 37.92 | 10.83 | 7.34 | 4.87 | 3.92 | 1.99 | 1.48 | 0.73[2] | 0.45[2] | | | | | | |
| 8 | 37.47 | 10.38 | 6.89 | 4.42 | 3.47 | 1.54 | 1.03 | 0.28[2] | | | | | | | |
| 9 | 37.19 | 10.10 | 6.61 | 4.14 | 3.19 | 1.26 | .75 | | | | | | | | |
| 10 | 36.44 | 9.35 | 5.86 | 3.39 | 2.44 | 0.51[2] | | | | | | | | | |
| 11 | 35.93 | 8.84 | 5.35 | 2.88 | 1.93 | | | | | | | | | | |
| 12 | 34.00 | 6.91 | 3.42 | 0.95 | | | | | | | | | | | |
| 13 | 33.05 | 5.96 | 2.47 | | | | | | | | | | | | |
| 14 | 30.58 | 3.49 | | | | | | | | | | | | | |
| 15 | 27.09 | | | | | | | | | | | | | | |

1

| No. | Treatment | No. | Treatment | No. | Treatment |
|---|---|---|---|---|---|
| 1 | 60-60-60 | 6 | 60-70-70 | 11 | 60-80-60 |
| 2 | 70-60-60 | 7 | 80-70-70 | 12 | 70-80-80 |
| 3 | 80-60-60 | 8 | 70-80-70 | 13 | 80-60-80 |
| 4 | 60-70-60 | 9 | 70-70-70 | 14 | 80-70-80 |
| 5 | 70-60-70 | 10 | 60-80-80 | 15 | 80-80-80 |

2 These differences are not significant. All other differences are significant (p = .05)

APPENDIX E Differences in iodine number between means of treatments in Exp. I

| Treatment | | Differences between treatment means (Iodine Number) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No.[1] | Mean | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 |
| 1 | 102.04 | 18.68 | 15.50 | 14.14 | 11.18 | 7.64 | 7.24 | 7.14 | 6.12 | 5.96 | 3.92 | 3.34 | 2.36 | 0.68 | 0.00[2] |
| 2 | 102.04 | 18.68 | 15.50 | 14.14 | 11.18 | 7.64 | 7.24 | 7.14 | 6.12 | 5.96 | 3.92 | 3.34 | 2.36 | 0.68 | |
| 3 | 101.36 | 18.00 | 14.82 | 13.46 | 10.50 | 6.96 | 6.56 | 6.46 | 5.44 | 5.28 | 3.24 | 2.66 | 1.68 | | |
| 4 | 99.68 | 16.32 | 13.14 | 11.78 | 8.82 | 5.28 | 4.88 | 4.78 | 3.76 | 3.60 | 1.56 | 0.98 | | | |
| 5 | 98.70 | 15.34 | 12.16 | 10.80 | 7.84 | 4.30 | 3.90 | 3.80 | 2.78 | 2.62 | 0.58[2] | | | | |
| 6 | 98.12 | 14.76 | 11.58 | 10.22 | 7.26 | 3.72 | 3.32 | 3.22 | 2.20 | 2.04 | | | | | |
| 7 | 96.08 | 12.72 | 9.54 | 8.18 | 5.22 | 1.68 | 1.28 | 1.18 | 0.16[2] | | | | | | |
| 8 | 95.92 | 12.56 | 9.38 | 8.02 | 5.06 | 1.52 | 1.12 | 1.02 | | | | | | | |
| 9 | 94.90 | 11.54 | 8.36 | 7.00 | 4.04 | 0.50[2] | 0.10 | | | | | | | | |
| 10 | 94.80 | 11.44 | 8.26 | 6.90 | 3.94 | 0.40[2] | | | | | | | | | |
| 11 | 94.40 | 11.04 | 7.86 | 6.50 | 3.54 | | | | | | | | | | |
| 12 | 90.86 | 7.50 | 4.32 | 2.96 | | | | | | | | | | | |
| 13 | 87.90 | 4.54 | 1.36 | | | | | | | | | | | | |
| 14 | 86.54 | 3.18 | | | | | | | | | | | | | |
| 15 | 83.36 | | | | | | | | | | | | | | |

1

| No. | Treatment | No. | Treatment | No. | Treatment |
|---|---|---|---|---|---|
| 1 | 85-85-55 | 6 | 85-85-70 | 11 | 85-85-85 |
| 2 | 70-70-55 | 7 | 85-70-70 | 12 | 70-85-85 |
| 3 | 70-55-55 | 8 | 70-70-70 | 13 | 55-85-85 |
| 4 | 55-55-55 | 9 | 55-70-70 | 14 | 70-70-85 |
| 5 | 85-55-55 | 10 | 55-55-70 | 15 | 55-55-85 |

2 These differences are not significant. All other differences are significant ($p = .05$)

APPENDIX F Differences in iodine number between means of treatments in Exp. II

| Treatment No.[1] | Mean | Differences between treatment means (Iodine Number) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 |
| 1 | 101.2 | 18.1 | 17.6 | 14.5 | 14.5 | 13.3 | 11.4 | 11.0 | 10.4 | 9.9 | 5.9 | 4.2 | 3.7 | 1.5 | 0.2[2] |
| 2 | 101.0 | 17.9 | 17.4 | 14.3 | 14.3 | 13.1 | 11.2 | 10.8 | 10.2 | 9.7 | 5.7 | 4.0 | 3.5 | 1.3 | |
| 3 | 99.7 | 16.6 | 16.1 | 13.0 | 13.0 | 11.8 | 9.9 | 9.5 | 8.9 | 8.4 | 4.4 | 2.7 | 2.2 | | |
| 4 | 97.5 | 14.4 | 13.9 | 10.8 | 10.8 | 9.6 | 7.7 | 7.3 | 6.7 | 6.2 | 2.2 | 0.5[2] | | | |
| 5 | 97.0 | 13.9 | 13.4 | 10.3 | 10.3 | 9.1 | 7.2 | 6.8 | 6.2 | 5.7 | 1.7 | | | | |
| 6 | 95.3 | 12.2 | 11.7 | 8.6 | 8.6 | 7.4 | 5.5 | 5.1 | 4.5 | 4.0 | | | | | |
| 7 | 91.3 | 8.2 | 7.7 | 4.6 | 4.6 | 3.4 | 1.5 | 1.1 | 0.5[2] | | | | | | |
| 8 | 90.8 | 7.7 | 7.2 | 4.1 | 4.1 | 2.9 | 1.0 | 0.6[2] | | | | | | | |
| 9 | 90.2 | 7.1 | 6.6 | 3.5 | 3.5 | 2.3 | 0.4[2] | | | | | | | | |
| 10 | 89.8 | 6.7 | 6.2 | 3.1 | 3.1 | 1.9 | | | | | | | | | |
| 11 | 87.9 | 4.8 | 4.3 | 1.2 | 1.2 | | | | | | | | | | |
| 12 | 86.7 | 3.6 | 3.1 | 0.0[2] | | | | | | | | | | | |
| 13 | 86.7 | 3.6 | 3.1 | | | | | | | | | | | | |
| 14 | 83.6 | 0.5[2] | | | | | | | | | | | | | |
| 15 | 83.1 | | | | | | | | | | | | | | |

1

| No. | Treatment | No. | Treatment | No. | Treatment |
|---|---|---|---|---|---|
| 1 | 70-60-60 | 6 | 60-70-60 | 11 | 80-80-80 |
| 2 | 80-60-60 | 7 | 80-70-70 | 12 | 60-80-60 |
| 3 | 60-60-60 | 8 | 60-70-70 | 13 | 70-80-70 |
| 4 | 70-70-70 | 9 | 80-60-80 | 14 | 60-80-80 |
| 5 | 70-60-70 | 10 | 80-70-80 | 15 | 70-80-80 |

2 These differences are not significant. All other differences are significant ($p = .05$)

APPENDIX G Differences in per cent protein between means of treatments in Exp. I

| Treatment No.[1] | Mean | Differences between treatment means (per cent protein) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 |
| 1 | 47.3 | 12.8 | 12.5 | 11.1 | 10.2 | 8.5 | 8.2 | 7.0 | 6.8 | 6.7 | 6.4 | 6.1 | 5.4 | 4.7 | 4.6 |
| 2 | 42.7 | 8.2 | 7.9 | 6.5 | 5.6 | 3.9 | 3.6 | 2.4 | 2.2 | 2.1 | 1.8 | 1.5 | 0.8 | 0.1[2] | |
| 3 | 42.6 | 8.1 | 7.8 | 6.4 | 5.5 | 3.8 | 3.5 | 2.3 | 2.1 | 2.0 | 1.7 | 1.4 | 0.7 | | |
| 4 | 41.9 | 7.4 | 7.1 | 5.7 | 4.8 | 3.1 | 2.8 | 1.6 | 1.4 | 1.3 | 1.0 | 0.7 | | | |
| 5 | 41.2 | 6.7 | 6.4 | 5.0 | 4.1 | 2.4 | 2.1 | 0.9 | 0.7 | 0.6[2] | 0.3[2] | | | | |
| 6 | 40.9 | 6.4 | 6.1 | 4.7 | 3.8 | 2.1 | 1.8 | 0.6[2] | 0.4[2] | 0.3[2] | | | | | |
| 7 | 40.6 | 6.1 | 5.8 | 4.4 | 3.5 | 1.8 | 1.5 | 0.3[2] | 0.1[2] | | | | | | |
| 8 | 40.5 | 6.0 | 5.7 | 4.3 | 3.4 | 1.7 | 1.4 | 0.2[2] | | | | | | | |
| 9 | 40.3 | 5.8 | 5.5 | 4.1 | 3.2 | 1.5 | 1.2 | | | | | | | | |
| 10 | 39.1 | 4.6 | 4.3 | 2.9 | 2.0 | 0.3[2] | | | | | | | | | |
| 11 | 38.8 | 4.3 | 4.0 | 2.6 | 1.7 | | | | | | | | | | |
| 12 | 37.1 | 2.6 | 2.3 | 0.9 | | | | | | | | | | | |
| 13 | 36.2 | 1.7 | 1.4 | | | | | | | | | | | | |
| 14 | 34.8 | 0.3[2] | | | | | | | | | | | | | |
| 15 | 34.5 | | | | | | | | | | | | | | |

1

| No. | Temperature | No. | Temperature | No. | Temperature |
|---|---|---|---|---|---|
| 1 | 55-55-85 | 6 | 55-85-85 | 11 | 70-70-55 |
| 2 | 70-70-85 | 7 | 70-70-70 | 12 | 70-55-55 |
| 3 | 70-85-85 | 8 | 85-85-85 | 13 | 85-55-55 |
| 4 | 85-85-70 | 9 | 55-70-70 | 14 | 85-85-55 |
| 5 | 55-55-70 | 10 | 85-70-70 | 15 | 55-55-55 |

2 These differences are not significant. All other differences are significant ($p = .05$)

APPENDIX H Differences in per cent protein between means of treatments in Exp. II

| Treatment | | Differences between treatment means (per cent protein) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No.[1] | Mean | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 |
| 1 | 47.9 | 11.2 | 9.9 | 8.8 | 6.1 | 5.0 | 4.3 | 3.7 | 3.6 | 3.6 | 3.4 | 2.7 | 2.3 | 1.7 |
| 2 | 46.2 | 9.5 | 8.2 | 7.1 | 4.4 | 3.3 | 2.6 | 2.0 | 1.9 | 1.9 | 1.7 | 1.0 | 0.6 | |
| 3 | 45.6 | 8.9 | 7.6 | 6.5 | 3.8 | 2.7 | 2.0 | 1.4 | 1.3 | 1.3 | 1.1 | 0.4 | | |
| 4 | 45.2 | 8.5 | 7.2 | 6.1 | 3.4 | 2.3 | 1.6 | 1.0 | 0.9 | 0.9 | 0.7 | | | |
| 5 | 44.5 | 7.8 | 6.5 | 5.4 | 2.7 | 1.6 | 0.9 | 0.3[2] | 0.2[2] | 0.2[2] | | | | |
| 6 | 44.3 | 7.6 | 6.3 | 5.2 | 2.5 | 1.4 | 0.7 | 0.1[2] | 0.0[2] | | | | | |
| 7 | 44.3 | 7.6 | 6.3 | 5.2 | 2.5 | 1.4 | 0.7 | 0.1[2] | | | | | | |
| 8 | 44.2 | 7.5 | 6.2 | 5.1 | 2.4 | 1.3 | 0.6 | | | | | | | |
| 9 | 43.6 | 6.9 | 5.6 | 4.5 | 1.8 | 0.7 | | | | | | | | |
| 10 | 42.9 | 6.2 | 4.9 | 3.8 | 1.1 | | | | | | | | | |
| 11 | 41.8 | 5.1 | 3.8 | 2.7 | | | | | | | | | | |
| 12 | 39.1 | 2.4 | 1.1 | | | | | | | | | | | |
| 13 | 38.0 | 1.3 | | | | | | | | | | | | |
| 14 | 36.7 | | | | | | | | | | | | | |

1

| No. | Temperature | No. | Temperature | No. | Temperature |
|---|---|---|---|---|---|
| 1 | 80-80-80 | 6 | 70-80-80 | 11 | 60-70-70 |
| 2 | 80-70-70 | 7 | 60-80-60 | 12 | 70-60-60 |
| 3 | 80-60-80 | 8 | 70-70-70 | 13 | 60-70-60 |
| 4 | 80-70-80 | 9 | 60-80-80 | 14 | 80-60-60 |
| 5 | 70-80-70 | 10 | 70-60-70 | | |

2 These differences are not significant. All other differences are significant (p = .05)

APPENDIX I

Seed size (grams per 100 seeds), per cent protein and per cent oil contents of rapeseed, refractive index and iodine number determinations within treatments (Exp. I).

| Treatment | Seed size | Protein content | Oil content | Refractive[1] index | Iodine no. |
|---|---|---|---|---|---|
| 55-55-55 | .3290 | 34.2 | 48.61 | 61.9 | 101.9 |
| | .3744 | 34.8 | 46.54 | 61.3 | 96.9 |
| | .3279 | | 49.97 | 61.4 | 97.6 |
| | .3716 | | 49.48 | 61.8 | 101.0 |
| | .3435 | | 48.96 | 61.8 | 101.0 |
| | .3242 | | | | |
| | .3244 | | | | |
| | .3626 | | | | |
| | .3224 | | | | |
| | .3247 | | | | |
| 55-55-85 | .2124 | 43.6 | 34.66 | 59.7 | 83.7 |
| | .2379 | 51.1 | 31.50 | 60.0 | 86.2 |
| | .2405 | | 31.23 | 59.6 | 82.8 |
| | .2055 | | 32.80 | 59.6 | 82.8 |
| | .2015 | | 32.82 | 59.4 | 81.3 |
| | .2304 | | | | |
| | .2027 | | | | |
| | .2157 | | | | |
| | .2144 | | | | |
| 55-55-70 | .2946 | 40.5 | 42.03 | 60.9 | 93.7 |
| | .2845 | 41.9 | 39.24 | 61.2 | 96.1 |
| | .2726 | | 36.02 | 61.2 | 96.1 |
| | .2909 | | 39.42 | 61.0 | 94.4 |
| | .2837 | | 44.67 | 60.9 | 93.7 |
| | .3449 | | | | |
| | .3267 | | | | |
| | .3220 | | | | |
| | .2876 | | | | |
| | .2790 | | | | |
| 55-85-85 | .1536 | 40.9 | 22.87 | 60.2 | 87.9 |
| | .1372 | | | | |
| | .1319 | | | | |

[1] Refractometer oil scale reading

APPENDIX I (continued)

| Treatment | Seed size | Protein content | Oil content | Refractive index | Iodine no. |
|---|---|---|---|---|---|
| 55-70-70 | .2790 | 40.0 | 41.81 | 61.1 | 94.4 |
| | .3392 | 40.6 | 41.85 | 61.1 | 94.4 |
| | .2836 | | 42.90 | 61.3 | 96.9 |
| | .2122 | | 40.72 | 61.0 | 94.4 |
| | .2674 | | 41.99 | 61.1 | 94.4 |
| | .2925 | | | | |
| | .3059 | | | | |
| | .2840 | | | | |
| | .3240 | | | | |
| 70-70-70 | .3022 | | 40.91 | 61.2 | 96.1 |
| | .2871 | 39.7 | 44.10 | 61.2 | 96.1 |
| | .2724 | 41.5 | 40.56 | 61.2 | 96.1 |
| | .2502 | | 38.72 | 61.3 | 96.9 |
| | .3199 | | 41.82 | 61.1 | 94.4 |
| | .3122 | | | | |
| | .3352 | | | | |
| | .2867 | | | | |
| | .3145 | | | | |
| 70-70-55 | .3692 | 38.8 | 47.91 | 61.8 | 101.0 |
| | .3535 | 38.7 | 47.57 | 61.9 | 101.9 |
| | .3810 | | 47.63 | 62.0 | 101.9 |
| | .3744 | | 48.18 | 62.0 | 102.7 |
| | .3940 | | 49.26 | 61.9 | 102.7 |
| | .3073 | | | | |
| | .4053 | | | | |
| | .3360 | | | | |
| | .4042 | | | | |
| | .4128 | | | | |
| 70-70-85 | .2738 | 41.3 | 38.41 | 60.0 | 86.2 |
| | .3229 | 44.0 | 33.86 | 60.1 | 87.0 |
| | .3677 | | 38.26 | 59.9 | 85.4 |
| | .2930 | | 34.30 | 60.0 | 86.2 |
| | .2770 | | 36.02 | 60.2 | 87.9 |
| | .2833 | | | | |
| | .2942 | | | | |
| | .3395 | | | | |
| | .3729 | | | | |

APPENDIX I (continued)

| Treatment | Seed size | Protein content | Oil content | Refractive index | Iodine no. |
|---|---|---|---|---|---|
| 70-55-55 | .3668 | 38.3 | 48.57 | 61.9 | 101.9 |
| | .3349 | 36.0 | 48.88 | 61.8 | 101.0 |
| | .3611 | | 49.54 | 61.8 | 101.0 |
| | .3589 | | 49.79 | 61.8 | 101.0 |
| | .3935 | | 50.31 | 61.9 | 101.9 |
| | .3853 | | | | |
| | .3846 | | | | |
| | .3521 | | | | |
| | .3832 | | | | |
| | .3643 | | | | |
| 70-85-85 | .1314 | 43.0 | 33.82 | 60.2 | 87.9 |
| | .1360 | 42.2 | 26.83 | 60.7 | 92.0 |
| | .1100 | | 24.93 | 60.9 | 93.6 |
| | .1769 | | 23.79 | 60.8 | 92.9 |
| | .1994 | | 29.29 | 60.2 | 87.9 |
| | .1503 | | | | |
| | .1284 | | | | |
| | .1020 | | | | |
| | .2218 | | | | |
| 85-85-85 | .1724 | 40.5 | 24.93 | 61.0 | 94.4 |
| 85-85-70 | .3020 | 42.7 | 38.17 | 61.8 | 101.0 |
| | .3527 | 41.2 | 41.44 | 61.7 | 100.2 |
| | .3622 | | 42.44 | 61.2 | 96.1 |
| | .3788 | | 43.25 | 61.6 | 99.3 |
| | .3467 | | 41.57 | 61.0 | 94.0 |
| | .3712 | | | | |
| | .3297 | | | | |
| | .3140 | | | | |
| | .3089 | | | | |
| | .3585 | | | | |
| 85-85-55 | .4182 | 35.0 | 49.97 | 62.0 | 102.7 |
| | .4310 | 34.6 | 50.39 | 61.5 | 98.5 |
| | .4059 | | 48.37 | 62.1 | 103.6 |
| | .3940 | | 51.20 | 62.0 | 102.7 |
| | .4330 | | 50.09 | 62.0 | 102.7 |
| | .4165 | | | | |
| | .3975 | | | | |
| | .4519 | | | | |
| | .4147 | | | | |
| | .4328 | | | | |

APPENDIX I (continued)

| Treatment | Seed size | Protein content | Oil content | Refractive index | Iodine no. |
|---|---|---|---|---|---|
| 85-70-70 | .2972 | 38.7 | 42.11 | 61.3 | 96.9 |
| | .3084 | 39.4 | 42.66 | 61.5 | 98.5 |
| | .3030 | | 44.13 | 61.2 | 96.1 |
| | .3210 | | 45.36 | 60.7 | 92.0 |
| | .3200 | | 44.03 | 61.3 | 96.9 |
| | .3431 | | | | |
| | .3262 | | | | |
| | .3633 | | | | |
| | .3204 | | | | |
| | .2985 | | | | |
| 85-55-55 | .4407 | 36.2 | 50.90 | 61.3 | 96.9 |
| | .4471 | 36.2 | 49.05 | 62.0 | 102.7 |
| | .3933 | | 51.01 | 61.5 | 98.5 |
| | .3919 | | 49.63 | 61.6 | 99.3 |
| | .4481 | | 49.58 | 61.2 | 96.1 |
| | .3891 | | | | |
| | .4123 | | | | |
| | .3810 | | | | |
| | .4138 | | | | |
| | .4244 | | | | |
| 85° F. day | .3553 | 43.1 | 37.24 | 60.2 | 87.9 |
| 55° F. night | .2947 | 44.3 | 38.43 | 60.0 | 86.2 |
| | .3099 | | 39.84 | 60.0 | 86.2 |
| | .3709 | | 39.88 | 60.0 | 86.2 |
| | .2351 | | 41.72 | 60.4 | 89.5 |
| | .2699 | | | | |
| | .3112 | | | | |
| | .2791 | | | | |
| | .3433 | | | | |
| | .3079 | | | | |

APPENDIX J

Seed size (grams per 100 seeds), per cent protein and per cent oil content of rapeseed, and refractive index and iodine number determinations within treatments. (Exp. II).

| Treatment | Seed size | Protein content | Oil content | Refractive index | Iodine no. |
|---|---|---|---|---|---|
| 60-60-60 | .3704 | No data | 47.90 | 61.9 | 101.9 |
| | .3273 | | 45.18 | 61.6 | 99.3 |
| | .3011 | | 47.94 | 61.3 | 96.9 |
| | .3362 | | 45.75 | 61.6 | 99.3 |
| | .3381 | | 46.95 | 61.8 | 101.0 |
| | .3100 | | | | |
| | .3759 | | | | |
| | .3364 | | | | |
| | .3313 | | | | |
| | .3490 | | | | |
| 60-70-60 | .3309 | 37.7 | 49.99 | 61.0 | 94.4 |
| | .3091 | 38.4 | 42.46 | 60.8 | 92.9 |
| | .3751 | | 45.13 | 61.2 | 96.1 |
| | .3521 | | 42.95 | 61.2 | 96.1 |
| | .3320 | | 42.69 | 61.3 | 96.9 |
| | .3605 | | | | |
| | .3529 | | | | |
| | .3520 | | | | |
| | .3263 | | | | |
| 60-70-70 | .3523 | 42.3 | 40.78 | 60.7 | 92.0 |
| | .3083 | 41.3 | 41.62 | 60.9 | 93.6 |
| | .3220 | | 42.42 | 60.9 | 93.6 |
| | .3257 | | 40.47 | 60.3 | 88.6 |
| | .3699 | | 39.84 | 60.0 | 86.2 |
| | .3590 | | | | |
| | .3456 | | | | |
| | .3615 | | | | |
| | .3223 | | | | |
| | .3524 | | | | |
| 60-80-60 | .3192 | 42.8 | 34.69 | 60.0 | 86.2 |
| | .2389 | 45.9 | 35.71 | 60.0 | 86.2 |
| | .3145 | | 36.16 | 60.5 | 90.3 |
| | .2908 | | 40.42 | 59.4 | 81.3 |
| | .3603 | | 32.69 | 60.4 | 89.5 |
| | .2773 | | | | |
| | .2825 | | | | |
| | .2741 | | | | |
| | .3006 | | | | |
| | .2825 | | | | |

APPENDIX J (continued)

| Treatment | Seed size | Protein content | Oil content | Refractive index | Iodine no. |
|---|---|---|---|---|---|
| 60-80-80 | .3002 | 42.2 | 38.67 | 59.4 | 81.3 |
| | .2753 | 45.0 | 38.05 | 60.3 | 88.6 |
| | .3068 | | 37.36 | 59.8 | 84.5 |
| | .2956 | | 33.56 | 59.0 | 77.9 |
| | .2672 | | 34.54 | 59.8 | 85.5 |
| | .2560 | | | | |
| | .2294 | | | | |
| | .2779 | | | | |
| | .2574 | | | | |
| | .2261 | | | | |
| 70-70-70 | .2542 | 43.5 | 36.04 | 61.5 | 98.5 |
| | .2678 | 44.6 | 36.89 | 61.0 | 94.4 |
| | .3002 | | 39.29 | 61.1 | 95.3 |
| | .3077 | | 39.35 | 61.9 | 101.9 |
| | .3610 | | 34.38 | 60.0 | |
| | .3220 | | | | |
| | .3686 | | | | |
| | .2905 | | | | |
| | .2822 | | | | |
| 70-60-70 | .3292 | 42.2 | 41.44 | 61.0 | 94.4 |
| | .2783 | 43.6 | 43.15 | 61.0 | 94.4 |
| | .2986 | | 41.89 | 61.4 | 97.6 |
| | .2686 | | 40.12 | 61.9 | 101.9 |
| | .3419 | | 40.57 | 61.3 | 96.9 |
| | .2723 | | | | |
| | .2728 | | | | |
| | .3585 | | | | |
| | .3715 | | | | |
| | .3712 | | | | |
| 70-60-60 | .3109 | 37.9 | 48.33 | 61.7 | 100.2 |
| | .3346 | 40.4 | 45.83 | 61.8 | 101.0 |
| | .3229 | | 47.37 | 61.6 | 99.3 |
| | .3326 | | 43.41 | 62.0 | 102.7 |
| | .3115 | | 42.06 | 62.0 | 102.7 |
| | .3346 | | | | |
| | .3148 | | | | |
| | .3213 | | | | |
| | .3303 | | | | |
| | .3137 | | | | |

APPENDIX J (continued)

| Treatment | Seed size | Protein content | Oil content | Refractive index | Iodine no. |
|---|---|---|---|---|---|
| 70-80-70 | .3198 | 45.7 | 38.71 | 60.0 | 86.2 |
| | .2196 | 43.4 | 38.03 | 60.0 | 86.2 |
| | .2768 | | 36.82 | 60.1 | 87.0 |
| | .3323 | | 38.82 | 60.0 | 86.2 |
| | .2397 | | 34.99 | 60.2 | 87.9 |
| | .2632 | | | | |
| | .2472 | | | | |
| | .2738 | | | | |
| | .3053 | | | | |
| | .2444 | | | | |
| 70-80-80 | .2954 | 44.3 | 32.66 | 59.3 | 80.4 |
| | .2841 | 44.3 | 35.79 | 59.9 | 85.4 |
| | .2789 | | 37.49 | 59.4 | 81.3 |
| | .2905 | | 31.70 | 60.0 | 86.2 |
| | .3261 | | 32.37 | 59.5 | 82.1 |
| | .2790 | | | | |
| | .2970 | | | | |
| | .3168 | | | | |
| | .2019 | | | | |
| 80-80-80 | .2398 | 47.6 | 27.32 | 60.1 | 87.0 |
| | .2704 | 48.2 | 28.36 | 60.2 | 87.9 |
| | .2347 | | 25.35 | 60.3 | 88.6 |
| | .1720 | | 27.32 | 60.2 | 87.9 |
| 80-60-80 | .3605 | 45.7 | 33.76 | 60.8 | 92.9 |
| | .2414 | 45.5 | 29.27 | 60.6 | 91.2 |
| | .3161 | | 33.01 | 60.0 | 86.2 |
| | .3134 | | 32.21 | 60.4 | 89.5 |
| | .2563 | | 37.01 | 60.6 | 91.2 |
| | .2175 | | | | |
| | .1914 | | | | |
| | .2813 | | | | |
| | .2153 | | | | |
| | .2592 | | | | |

APPENDIX J (continued)

| Treatment | Seed size | Protein content | Oil content | Refractive index | Iodine no. |
|---|---|---|---|---|---|
| 80-60-60 | .2691 | 38.5 | 43.21 | 61.9 | 101.9 |
| | .3609 | 35.1 | 38.04 | 61.7 | 100.2 |
| | .3231 | | 47.75 | 62.0 | 102.7 |
| | .3244 | | 48.02 | 61.6 | 99.3 |
| | .3457 | | 47.05 | | |
| | .3459 | | | | |
| | .3097 | | | | |
| | .3602 | | | | |
| | .3153 | | | | |
| | .3783 | | | | |
| 80-70-80 | .2378 | 45.6 | 30.08 | 60.8 | 92.9 |
| | .2397 | 44.9 | 28.56 | 60.8 | 92.9 |
| | .1531 | | 30.42 | 60.5 | 90.3 |
| | .2206 | | 33.81 | 60.1 | 87.0 |
| | .2081 | | 30.02 | 60.0 | 86.2 |
| | .2168 | | | | |
| | .2444 | | | | |
| | .2735 | | | | |
| | .2000 | | | | |
| 80-70-70 | .3686 | 44.6 | 38.27 | 60.3 | 88.6 |
| | .3624 | 47.7 | 43.64 | 60.9 | 93.6 |
| | .3059 | | 35.51 | 60.0 | 86.2 |
| | .3534 | | 37.75 | 60.9 | 93.6 |
| | .2855 | | 34.45 | 61.0 | 94.4 |
| | .2585 | | | | |
| | .4024 | | | | |
| | .3454 | | | | |
| | .3266 | | | | |