Cultural studies with two species of mustard grown at three locations
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A THESIS Submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of Master of Science in Agronomy at Montana State College
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Abstract:
The effect of seed size, rate of seeding, and seeding depth on the yield and quality of the two species of mustard, Brassica iuncea (L. Cosson) and Brassica hirta (Moench), was determined under irrigated condition at Bozeman and non-irrigated conditions at Havre and Sunburst, Montana. No significant differences were observed due to seed size of the two species. Seeding depth and seed size did influence emergence in the greenhouse. The effect was the same for both the species. The smaller sized seed gave a lower percentage of emergence at the lower depth of seeding. Seed of different sizes, when planted at a constant depth, influenced field stand. Differences in field stand caused by seed size differences were significantly different for the two species and at two locations. Highest yields were obtained from the largest seed of both the species when seeded at rates of five pounds per acre and 9.7 pounds per acre for oriental yellow mustard and yellow mustard, respectively. The five pounds seeding rate produced an optimum stand of 110 plants per 16 square feet of oriental yellow mustard on irrigated land. It was not, established whether the maximum 105 plants per 16 square feet established with yellow mustard was the optimum number of plants for this species. The seed produced from this optimum stand had the highest seed size index and nearly the highest test weight.

Seed size planted and seeding rates influenced significantly the stand and the number of pods per terminal raceme. Number of seed per pod and seed weight were not significantly influenced by either seed size planted or seeding rate. A high number of seed per pod was associated with smaller seed.

Stand influenced the number of pod per terminal raceme, number of seed per pod, yield, seed size and test weight. An optimum stand of 100-110 plants per 16 square feet of oriental yellow mustard produced the best yield, highest seed size index and approached a nearly maximum test Weight. In yellow mustard it could not be established that 105 plants per 16 square feet was optimum as higher stands were not obtained. Of the stands obtained, this was optimum for this species.

A difference in stand in either direction from the optimum resulted in lower yields, seed size index and test weight in oriental yellow mustard, and any reduction in stand of yellow mustard resulted in lower yield, lower seed size index and lower test weight.

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ABSTRACT

The effect of seed size, rate of seeding, and seeding depth on the yield and quality of the two species of mustard, Brassica juncea (L. Cosson) and Brassica hirta (Moench), was determined under irrigated conditions at Bozeman and non-irrigated conditions at Havre and Sunburst, Montana. No significant differences were observed due to seed size of the two species. Seeding depth and seed size did influence emergence in the greenhouse. The effect was the same for both the species. The smaller sized seed gave a lower percentage of emergence at the lower depth of seeding. Seed of different sizes, when planted at a constant depth, influenced field stand. Differences in field stand caused by seed size differences were significantly different for the two species and at two locations. Highest yields were obtained from the largest seed of both the species when seeded at rates of five pounds per acre and 9.7 pounds per acre for oriental yellow mustard and yellow mustard, respectively. The five pounds seeding rate produced an optimum stand of 110 plants per 16 square feet of oriental yellow mustard on irrigated land. It was not established whether the maximum 105 plants per 16 square feet established with yellow mustard was the optimum number of plants for this species. The seed produced from this optimum stand had the highest seed size index and nearly the highest test weight.

Seed size planted and seeding rates influenced significantly the stand and the number of pods per terminal raceme. Number of seed per pod and seed weight were not significantly influenced by either seed size planted or seeding rate. A high number of seed per pod was associated with smaller seed.

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A difference in stand in either direction from the optimum resulted in lower yields, seed size index and test weight in oriental yellow mustard, and any reduction in stand of yellow mustard resulted in lower yield, lower seed size index and lower test weight.

INTRODUCTION

Size or plumpness of seed has always attracted the attention of producers as well as consumers in every walk of life. Good sized flowers, fruits and seeds arouse interest of the consumers. Producers also take pride in large seed, flowers and fruits. Farmers are interested in over-all production and the test weight of the seed in addition to size. His main interest is to get maximum return per acre. This may be influenced by yield as well as by quality which in turn may be influenced by size of seed planted and seeding rate. A constant seeding rate is usually considered as compensatory for any differences in size of seed planted.

Yield in mustard may be represented by (plants per unit area) X (number of pods per plant) X (number of seed per pod) X (weight per seed). Seed quality and seeding rate would probably not affect each of these components of yield equally. An understanding of the influence of each yield component on yield and quality should be useful in realizing maximum return per acre from mustard.

Mustard seed contractors are interested in a method of forecasting seed production before harvest. Since three of the components of yield can be determined considerably before harvest time, it should be possible to predict yields with considerable accuracy at that time, particularly if the fourth component, seed weight, is not materially influenced by environment.

From the plant breeders point of view, it would be of help to know the extent to which factors such as components of yield, vigor of plants, etc. contribute to yield. If a breeder could know definitely to what extent the yield components were influenced by environment, he might, while selecting for genetic differences in yield, give proper discount to the environmental effect and select for higher yield with greater confidence in his results.

Other workers have tried to establish a correlation between number of pods, number of seed per pod, weight of seed per pod, or weight of seed, to yield of individual plants. The range of variation, as reported by them, is great and there is still need for further refinement in methods of measurement.

The objective of the present study was to determine the effect of different sizes of seed on yield and some of the components which affect yield in two of the three types of mustard grown commercially in Montana. Effect of rate of seeding on production of quality and quantity of seed was also studied. Attempts were made to determine which correlations between yield components and yield might help in forecasting yield before harvest.

The experiments were conducted at three locations at Bozeman on irrigated land, and at Havre and Sunburst on dryland, the latter two locations being nearer to the principal mustard growing areas of Montana.

LITERATURE REVIEW

Seed quality although difficult to define is of primary importance in plant production. Many studies have been made on the effect of different factors on the yield and quality of all kinds of commercially produced seed. Relatively little work has been done with mustard to determine the effect of seed size, planting depth, seeding rate and variety on emergence, seedling vigor, and yield.

Reports of some workers who have investigated the relationship between seed size, germination, stand, seedling vigor, growth, and yield, are cited here. In most of the citations, only two or three size categories of seed, large and small or large, medium and small have been a subject of study. Early investigations were devoted mostly to seed size in relation to germination, stand and yield. In this connection, the work of Miller and Pammel (14), Cummings (2), Rotuno (20), Oexmann (17), Kieselbach (9, 10, 11), and Erickson (3) may be mentioned. They all determined the superiority of large seed over small seed, except Kieselbach and Rotuno who found some conflicting results discussed later. Recent work by Kaufmann (8) is similar, large seed in Barley produced more vigorous seedlings than small seed. He further states that large seed produced plants with more tillers than those grown from small seed.

Work done by Kneebone (12) with native grass species supports the views of other workers in regard to higher vigor of large seed, but does not support the finding of better germination. He states that the larger the seed within a lot, the more vigorous are the seedlings grown from it. Seedlings from larger seed emerged faster and grew at a faster rate, but seed size had little or no effect on germination.

Another group of investigators obtained results which led them to believe that medium sized seed was superior to large seed and small seed. Hickman found that second grade wheat (after screening) gave the highest yield in bushels as compared to other sizes. Harris (cited by Kiesselbach) working with Phasolus vulgaris could conclude "Both large and small seeds are less capable of developing into fertile plants than those which do not deviate so widely above or below the type."

Still another group of workers are undecided as to which size is the best. Kiesselbach (9), working on oats, found smaller seed to yield better in one type while larger seed yielded better in another type. Rotuno's (2) results in radish are similar. He stated that results obtained with one variety are not necessarily comparable with another variety.

Planting seed at different depths can also seriously influence emergence and stand. Stitt (21) reports reduction in stand from seeding soybeans deeper than 2 inches in sandy soil and one inch in a clay soil. Increasing depth of planting caused a progressively lower germination. He states that smaller seeded varieties germinated in less time and better than larger seeded varieties when seeded at deeper depths. Rogler (19), working with wheat grass, reported that rate of emergence was approximately the same for all weight classes of seed planted at 1/2 inch depth, but below one inch depth the germination decreased and this decrease was comparatively more for small seed. He used six seed size categories and in most cases the number of seedlings emerging declined rapidly for each class as the depth of planting increased. Murphy and Arny (15), McKenzee, Heinrich, and Anderson (13); Erickson (3) and Beveridge and Wilsie (1) reported decreases in seedling emergence as depth of seeding increased. The decrease was greatest when seed was sown more than one inch below the soil surface. Plummer, (18) working with grass seed, reported seeding depths of 1/4 inch to be the most desirable depth for planting under favorable moisture condition. Deeper depths, while not preventing appearance of the shoot, resulted in a marked reduction in emergence. Within wide limits, weight of seed is probably a factor in emergence from the deeper depth, but does not appear to be an influence at shallower depths within a narrow range.

Interaction of depth of seeding and seed size as part of the germination complex has been shown by Rogler (19), Erickson (9), and Beveridge and Wilsie (1). The first two authors, while working on wheat grass and alfalfa, found that as depth of seeding was increased, the advantage of large seed over small seed became increasingly apparent. Beveridge and Wilsie (1) report - "Values for correlations of seed size with emergence and rate of emergence obtained throughout the study were not significant. Their variability emphasized lack of consistency among responses to seed size at different depths and rates of emergence.

The relationship between seed size and seedling vigor on the other hand was particularly strong." Rogler reports significant relationship between seed size and seedling vigor.

The above citations indicate that though large seed has been found to perform better in the majority of instances, it is not always superior. In almost all studies, only distinct size categories have been used.

In addition to seed size and seeding depth, rate of seeding is another variable which has attracted considerable research in recent years. Studies have been concerned with the relationship of stand, yield and certain other plant characteristics related to yield. Kieselbach (11) working with wheat, barley and oat seed concluded that seeding rate materially influenced yield and that even though the range of variation in yield is great; test weight is little affected. Thayer and Rather (22) worked with barley. They studied several factors which might be influenced by seeding rate. According to them, the number of plants per unit area increased and tillering, length of head, number of kernels per head, and weight of 1000 kernels decreased as the rate of seeding was increased. Varieties differed in the rate of decrease of these variables. Rates of seeding which gave maximum acre yields were not a single rate, but rather a wide range of seeding rates. An increase in seeding rate beyond this range caused considerable reduction in growth and finally reduction in yield.

Woodward (24) working with small grain crops, reported larger heads and kernels and higher test weight from a lighter seeding rate.

Grafius (6) working with oats obtained similar results. According to him, variations of seeding rate around the optimum seem to cause only minor variations in tillering and subsequent yield. Wiggans and Frey (23) approached the effect of seeding rates somewhat differently. They state that, "Regardless of the increase in rates of seeding, there apparently is a maximum number of head producing culms which can be produced on a given area. At lower than optimum rates of seeding, many plants must produce more than one head bearing culm per plant in order that maximum use can be made of available growth factors. At plant populations above the maximum that can be supported by the available light, moisture and nutrients available, some culms fail to survive."

Fulkerson (5) working with orchard grass reports little variation in yield due to differences in seeding rates. He found a positive correlation between number of fertile culms and yield for the first two years, but a negative correlation for the third year. Seed weight was negatively correlated with yield, though the correlation was not significant. Correlations between number of seed per panicle and other characteristics were found to vary from one year to another. He concluded that, of the three yielf components, number of culms, number of seed per culm, and seed weight; seed weight though negatively associated, is not as important in determining yield as the other two components. He considered the number of culms the most important factor. These variations in results obtained by several workers in a variety of crops indicate a need for similar studies with mustard to determine the interaction of yield components under varying environments.

A recent approach to yield components and perhaps yield estimates has been suggested by Grafius (6). "Three components of yield in oats - number of panicles per unit area (x), the average number of kernels per panicle (y) and the average kernel weight (z) may be interpreted as the edge of a rectangular parrellelepid with yield as value (w). Greater increase in yield can be achieved by increasing the short edge of the parrellelepid of an otherwise good variety."

A similar approach can be used for prediction of mustard yield (y) represented by volume of a triangular prism. Four sides of this prism may be represented by: number of plants (a); number of pods (a); number of seed per pod (c); and weight of seed (d).

MATERIALS AND METHODS

Commercial lots of two mustard species namely yellow (*Brassica hirta*, Moench) and Oriental yellow (*Brassica juncea*, L. Cosson) (16) were used in these studies. In all field experiments, plots consisted of 4 rows 10 feet long and 8 feet from each of the two central rows were harvested.

The analysis of variance technique has been used for the analysis of data and the F test as the test of significance. Duncan's Multiple Range Test has been used throughout to determine the significant classes or groups.

Methods of correlation and regression have been used to determine the relation of yield components to yield, seed size, and test weight.

Seed of the two mustard species was sieved through a set of ½ inch slotted sieves of 1/12 inch, 1/14 inch, 1/16 inch, 1/18 inch, 1/20 inch, and 1/22 inch width by shaking the sieves from side to side, parallel with the slots with a twelve inch stroke for twenty strokes. Seed remaining on top of the sieves, as well as that which passed through the 1/22 inch sieve, was weighed individually and expressed as percentage of total weight. These percentages were multiplied, respectively, by coefficients of 6, 5, 4, 3, 2, 1, and 0. The sum of the products of all these gave the estimate of the relative seed size or the "seed size index" as reported (11) throughout this paper. All seed passed through a 1/12 inch sieve in the case of the Oriental Yellow mustard and no seed passed through a

1/22 inch sieve in the case of Yellow mustard. Only six sizes of seed of each of the two mustard species were used for planting.

Four experiments were designed and conducted and are described below:

1. Emergence test in the green house:- The six seed size categories of each of the two mustard types were planted at one, two and three inch depths in a Manhattan fine sandy loam soil in flats placed in the greenhouse. The experiments consisted of three replications in a split-split plot design with species and depths of planting as main plots and seed sizes allocated at random in plots of planting depths. One-hundred seed per plot were planted and the data are reported as per cent emergence.

2. Seed size field trial with constant number of seed planted per unit area:- Twelve viable seed per foot of row were sown, for the six seed size categories of each mustard species, under field conditions at Bozeman, Havre and Sunburst. The six seed size categoreis of each of the two mustard species were planted in a split plot design of four replications. The main plots were species in which sub-plots of seed sizes were randomly distributed.

Number of plants per 16 square feet of harvested row at Bozeman and Havre is reported as emergence of different seed sizes under field conditions.

Data regarding yield, test weight and seed size index were obtained for the three locations and tests for significance were made. Coefficients of variability were determined.

Number of seed per pod, weight of 100 seed and number of pods on the main raceme was determined on the Bozeman tests. Two pods each from ten random plants per plot were collected, seed counted and weighed and the average number of seed per pod and weight of 100 seed per plot calculated. The Average number of pods on the main raceme was determined by averaging number of pods on the main raceme of ten random plants of each plot. Average heights of plants in inches was measured at Bozeman.

3. Seed size trial with constant seeding rate per acre:- A constant weight of viable seed of six different seed sizes of each of two mustard species at the rate of five pounds to an acre was planted at Bozeman. The design was a split plot with four replications. Species constituted the main blocks in which plots of seed sizes were randomly distributed.

Data on yield, seed size index, test weight, average number of pods on the main raceme, number of seed per pod, weight per 100 seed, average height of plants and number of plants per unit area were collected for analysis.

4. Rate of seeding trial:- Two species of mustard were each planted at ten different seeding rates varying from one to ten pounds per acre at one pound increments. A split plot design with four replications was used at three locations Bozeman, Havre, and Sunburst. The main plots consisted of species in which plots of rates were randomly distributed.

Data on yield, test weight and seed size index were collected from the plantings at three locations. Data on number of plants per unit area were collected at Bozeman and Havre and recorded as emergence.

Data regarding number of pods on the main raceme, number of seed per pod and weight per 100 seed were collected at Bozeman in the manner described earlier.

RESULTS

A. Effect of sizing on germination and test weight of seed used in trials:- Germination in yellow mustard was somewhat higher than the oriental yellow as may be observed in Table I. The germination percentage for yellow mustard averaged 99 per cent as compared to 94 per cent for oriental yellow mustard.

In yellow mustard, there does not appear to be any real differences due to size of seed. Lower germination is apparent for the large and small sizes of oriental yellow.

No ready explanation is available for the lower germination of the largest seed of oriental yellow. It may be that some seed absorbed moisture, swelled and partially germinated before sizing. This swelling and partial germination could result in lower test weight and lower germination.

The smallest seed of oriental yellow has a low test weight and lower germination. This is probably due to greater percentage of shrivelled or immature seed in the smaller sized seed of oriental yellow.

B. Factors influencing emergence:- The mean values for emergence, and analysis of variance for emergence, of six seed sizes of each of two mustard species grown at three depths of planting in the greenhouse are recorded in Table II and Table III, respectively. The analysis shows that variations due to types of mustard planted is not significant. Variation in emergence due to size and due to depths are significant at the 1 per cent level of probability. There are no significant differences due to the interactions seed size x depth; seed size x

Table I. Relation of seed weight, test weight, and germination percentage of six different sizes of each of two mustard species.

Species of Mustard	Seed Size Index	Sizes	Size No	Weight per 100 Seed grams.	Test Weight lb/bu	Germination per cent
Oriental Yellow	500	on 1/14	1	0.45	53.2	87
	400	on 1/16	2	0.39	53.9	98
	300	on 1/18	3	0.33	53.2	97
	200	on 1/20	4	0.26	53.2	100
	100	on 1/22	5	0.21	53.2	100
	0	thru 1/22	6	0.14	50.1	81
	Average			0.30	52.8	94
Yellow	600	on 1/12	1	0.78	55.9	100
	500	on 1/14	2	0.59	55.5	100
	400	on 1/16	3	0.49	55.5	98
	300	on 1/18	4	0.42	55.5	100
	200	on 1/20	5	0.35	55.5	96
	100	thru 1/20	6	0.30	54.3	100
	Average			0.49	55.4	99

Table II. Average percentage of emergence from 100 seed of six different seed sizes of each of two mustard species, planted at three different depths in flats, in the greenhouse

Species of Mustard	Size No.	Laboratory Germination Percentage of seed	Per cent Emergence From Depth of 1 inch	2 inch	3 inch	Average Percentage Emergence from all Depths*
Oriental Yellow	1	87	34	30	21	28
	2	98	36	31	17	28
	3	97	42	33	21	32
	4	100	36	27	9	24
	5	100	23	21	5	16
	6	81	20	16	0	12
	Average	94	32	26	12	23
Yellow	1	100	36	27	8	24
	2	100	36	25	8	23
	3	98	31	26	4	20
	4	100	30	16	0	15
	5	96	21	16	1	12
	6	100	11	2	0	4
	Average	99	28	19	3.5	16
Both Species	1	94	35	28	14	26 a
	2	99	36	28	12	25 a
	3	98	36	30	12	26 a
	4	100	33	22	4	20 b
	5	98	22	18	3	14 c
	6	90	16	9	0	8 d
	General Means*	96	30 a	22 a	8 b	20

* Values followed by the same letter are not significantly different from each other at the 5 per cent probability level.

Table III. Analysis of variance of per cent emergence from 100 seed of six different seed sizes of each of two mustard species planted at three different depths in flats in the greenhouse.

Source of Variation	Degrees Of Freedom	Mean Square
Types of Mustard	1	1285.2
Error (A)	2	299.1
Depth of Planting	2	4564.2**
Error (B)	4	159.8
Seed sizes planted	5	989.1**
Seed sizes x depth	10	36.55
Seed sizes x types	5	47.7
Types x depth	2	53.8
Seed sizes x types x depth	10	39.67
Error	64	52.65

$s_{\bar{y}}$ for sizes = 1.71 $s_{\bar{y}}/\bar{y}$ = 8.5 per cent
$s_{\bar{y}}$ for depths = 2.10 $s_{\bar{y}}/\bar{y}$ = 10.5 per cent

** Significant at one per cent level

species; species x depth and seed size x species x depths of planting. Changes in emergence due to depths of planting are not different for the various seed sizes or for types of mustard. Changes in emergence due to seed size are not dependent on types of mustard planted or depth of planting.

Data on emergence, from the same seed sizes of the two mustard species, grown in the field at Bozeman at two different seeding rates and at Havre at one seeding rate, are recorded in Table IV and the analysis of variance is recorded in Table V. Depth of seeding was constant. Results obtained indicate that differences in emergence due to species are significant at the 1 per cent level. Differences in emergence due to size of mustard seed planted are significant, as is the species x seed size interaction for all three tests. This indicates that there are significant differences in field emergence due to size of seed planted for the two species and the differences due to size are not the same for both species.

Further analysis of the data on average stand, by application of Duncan's Multiple Range Test, shows that significantly higher emergence was obtained from larger seed sizes when the seeding rate used was 12 viable seed per square foot for all sizes. A significantly higher emergence was obtained from the smallest seed size of oriental yellow when a constant seeding rate of five pounds per acre was used for all seed sizes.

Data on emergence obtained from ten rates of seeding of two mustard species and the analysis of variance are recorded in Table VI and Table VII, respectively. Differences in emergence due to species are significant at both locations. Differences in emergence due to different rates of planting are significant at the 1 per cent level at both locations. At Bozeman, the influence of rate on emergence

Table IV. Average field stand obtained from six different seed sizes of each of two mustard species grown at one rate of seeding at Havre and at two rates of seeding at Bozeman.

Species of Mustard	Size No.	Seeding Rate* Pounds Per Acre	Average Number of Plants Per 16 Square Feet When Seeding Rates of Viable Seed Is 12 Per Square Feet: Bozeman	12 Per Square Feet: Havre	5 Pounds per acre**: Bozeman
Oriental Yellow	1	5.2	104a	73b	100c
	2	4.5	88	81b	103c
	3	3.8	104a	115a	130b
	4	2.9	92b	80b	144b
	5	2.3	81bc	64b	146b
	6	1.6	52d	68b	169a
	Average	3.4	87	80	132
Yellow	1	9.7	106a	80a	96ab
	2	6.8	106a	64a	98ab
	3	5.7	109a	78a	86abc
	4	4.8	92b	63a	105a
	5	4.0	86b	65a	73c
	6	3.3	65c	30b	81b
	Average	5.7	94	63	90
Average for Both Species	1	7.4	105a	76b	98b
	2	5.6	97ab	72bb	100b
	3	4.8	106a	96a	108ab
	4	3.8	92ab	72bc	124a
	5	3.2	84b	64c	110ab
	6	2.4	58c	49d	125a
	General Mean	4.5	90	72	111

* Viable seed at 12 seed per square foot rate.

** Values for a species located followed by the same letter are not significant from each other at the 5 per cent level.

Table V. Analysis of variance of field stands obtained from six different seed sizes of each of two mustard species, planted at one rate of seeding at Havre and at two rates of seeding at Bozeman.

Source of Variation	Degrees of Freedom	Mean Square for Stand per 16 Square Feet When Seeding Rate of Viable Seed is: 12 per square foot — Bozeman	5 pounds per acre — Havre	5 pounds per acre — Bozeman
Species of Mustard	1	638.0	3383.5*	21168.0*
Error A	3	273.9	305.4	1432.1
Seed Size Planted	5	2360.5**	1938.5**	11041.2*
Error B	15	217.4	177.5	250.7
Species X Sizes	5	267.4**	755.44**	2318.7**
Error	15	53.2	131.23	186.1
$s_{\bar{y}}/\bar{y}$ for Both Species		5.21	3.71	5.59
$s_{\bar{y}}/\bar{y}$ Within Species		3.65	5.72	6.82
$s_{\bar{y}}/\bar{y}$ Both Species -%		5.8	5.1	5.0
$s_{\bar{y}}/\bar{y}$ Within Species -%		4.1	7.9	6.2

* Significant at 5 percent level
** Significant at 1 percent level

Table VI. Average field stand obtained from ten seeding rates of each of two mustard species when grown at Bozeman and Havre.

Species Of Mustard	Seeding Rate in Pounds Per Acre	Average Number of Plants Per 16 Square Feet At*	
		Bozeman	Havre
	lbs/Acre	no.	no.
Oriental Yellow	1	28 j	36
	2	44 i	48
	3	55 h	65
	4	66 g	87
	5	112 f	97
	6	120 e	94
	7	132 d	108
	8	154 c	105
	9	172 b	105
	10	187 a	127
	Average	107	87
Yellow	1	18 f	23
	2	35 e	42
	3	40 e	39
	4	66 d	53
	5	67 d	58
	6	79 c	55
	7	83 c	86
	8	99 b	87
	9	98 b	67
	10	112 a	84
	Average	70	59
Average for Both Species	1	23 j	30 e
	2	40 i	45 d
	3	49 h	52 d
	4	66 g	70 c
	5	90 f	78 c
	6	100 e	75 c
	7	108 d	97 ab
	8	126 c	94 ab
	9	135 b	86 bc
	10	154 a	106 a
General Mean		89	73

* Values for a species location followed by the same letter are not significant from each other at the 5 per cent level.

Table VII. Analysis of variance of stand obtained from ten seeding rates in each of two mustard species grown at Bozeman, and Havre.

Sources of Variation	Degrees of Freedom	Mean Square for Number of Plants Per 16 Square Feet	
		Bozeman	Havre
Species of Mustard	1	28087.5**	16159.6**
Error A	3	379.9	47.2
Seeding Rate	9	14775.1**	4764.4**
Rates x Species	9	1464.4**	311.2
Error B	54	29.8	218.6

$s_{\bar{y}}$ for both species	1.9	5.2
$s_{\bar{y}}$ within species	2.7	7.4
$s_{\bar{y}}/\bar{y}$ both species, per cent	2.2	5.8
$s_{\bar{y}}/\bar{y}$ within species, per cent	3.1	8.3

** Significant at 1 per cent level.

is significantly different for the two species. This difference of the species was not observed at Havre.

C. Factors influencing yield:- Mean yields in pounds per acre of two mustard species as influenced by seed size, locations, and seeding rates are recorded in Tables VIII and IX. Analysis of variance for the three locations separately, and a complex analysis of variance for the three locations combined are reported in Tables X to XIII. Correlation coefficients (r) and the regression of yield (y) on number of plants (x), - (b_{yx}) were determined and recorded in Table XIV. Correlation coefficients and regression coefficients were calculated so as to eliminate the effect of seed size.

Results obtained from Havre and Sunburst when a constant number of seed per unit area was planted, indicate differences in yield of the two mustard species, but no significant differences in yield due to differences in seed size planted. A non-significant trend towards higher yields from the larger seeed may be noted. At Bozeman, significant differences due to size of seed planted were observed. Results were consistent for both species. Average yields of both species were the same at Bozeman. It is suggested, that vigorously growing seedlings obtained from large seed need more moisture than seedlings obtained from small seed. Since moisture is limiting on dryland, the result may be a checking of the growth of the vigorously growing plants obtained from large seed. This could result in no marked yield differences due to seed size planted on dry land in certain years.

Table VIII. Average yield from six different seed sizes of each of two mustard species grown at one rate of seeding at Havre and Sunburst and at two rates of seeding at Bozeman.

Species of Mustard	Size No.	Average Yield in Pounds Per Acre When Seeding Rate of Viable Seed is*				
		12 Per Square Foot				5 Pounds Per Acre
		Bozeman	Havre	Sunburst	Average	Bozeman
Oriental Yellow	1	1928	480	613	1007	2036
	2	1682	426	613	907	2090
	3	1718	468	625	937	1969
	4	1435	402	529	789	2042
	5	1634	396	577	869	1760
	6	1153	402	540	698	1916
	Average	1592	429	583	868	1969
Yellow	1	1946	270	540	919	1730
	2	1573	258	510	780	1754
	3	1856	246	553	885	1754
	4	1778	288	540	869	1802
	5	1609	180	553	781	1910
	6	1249	240	516	668	2174
	Average	1668	247	535	817	1854
Average for Both Species	1	1937a	375	576	963a	1883
	2	1628a	342	562	844ab	1922
	3	1787a	357	589	911ab	1862
	4	1606ab	345	534	829ab	1922
	5	1622ab	288	565	825b	1835
	6	1201b	321	528	683c	2045
	General Mean	1630	338	559	842	1912

* Values for a species location followed by the same letter are not significant from each other at the 5 per cent level.

Table IX. Average yield from ten seeding rates of each of two mustard species grown at Bozeman, Havre and Sunburst.

Species of Mustard	Seeding Rate in Pounds Per Acre	Yield in Pounds Per Acre* Bozeman	Havre	Sunburst	Average
Oriental Yellow	1	1502	248d	482	744
	2	2005	398c	473	959
	3	1906	479a	534	973
	4	2044	404bc	468	972
	5	2218	411bc	570	1066
	6	2203	407bc	524	1045
	7	2140	389c	506	1012
	8	2233	485a	576	1098
	9	2656	420b	555	1210
	10	2260	503a	558	1107
	Average	2217	414	525	1018
Yellow	1	996	128f	341	488
	2	1340	171e	404	638
	3	1269	209d	476	651
	4	1702	263bc	453	806
	6	1476	284ab	450	737
	7	1783	314d	435	844
	8	1840	231c	431	834
	9	1816	260b	434	837
	10	1702	299a	398	800
	Average	1568	240	428	745
Average for Both Species	1	1249e	188e	412	616e
	2	1672cd	284d	438	798d
	3	1588d	344bc	505	812cd
	4	1873bc	334bc	460	889bcd
	5	1849bcd	348bc	510	902bc
	6	1980ab	323c	493	932ab
	7	1962a	352b	470	928ab
	8	2036a	358b	504	966ab
	9	2236a	340bc	494	1023
	10	1981ab	401a	478	953ab
	General Mean	1843	327	476	882

Table X. Analysis of variance of yield in grams from six different seed sizes of each of two mustard species grown at one rate of seeding at Havre and Sunburst and at two rates of seeding at Bozeman.

Sources of Variation	Degrees of Freedom	Mean Square for Yield in Grams Per Plot When Seeding Rate of Viable Seed Is: 12 Per Square Foot			5 Pounds Per Acre
		Bozeman	Havre	Sunburst	Bozeman
Species of Mustard	1	2017.0	11224.0**	760.1**	4408.4
Error A	3	1232.8	113.6	130.8	2735.8
Seed Size Planted	5	13540.0**	215.5	136.24	1202.5
Error B	15	3507.0	84.7	180.02	1669.6
Size x Species	5	1380.2	101.1	81.38	3593.9
Error C	15	4910.4	143.1	149.84	1489.2
$s_{\bar{y}}$ for sizes of both species		125.5	-	-	-
$s_{\bar{y}}/\bar{y}$ for sizes of both species		7.7	5.8	5.1	4.5

* Significant at 5 per cent level.
** Significant at 1 per cent level.

Table XI. Complex analysis of variance of yield in grams for six different seed sizes of each of two mustard species grown at three locations and planted at a rate of 12 viable seeds per square foot.

Source of Variation	Degrees of Freedom	Mean Square
Locations	2	634301.5**
Error (A)	6	4658.7
Species of Mustard	1	2508.4
Species x Location	2	5695.4**
Error (B)	9	504.8
Seed Size Planted	5	6082.9**
Seed Size x Location	10	3905.4**
Error (C)	45	1265.4
Species x Sizes	5	867.8
Species x Sizes x Location	10	1356.6
Error (D)	45	1510.2
$s_{\bar{y}}$ for sizes of both species		43.4
$s_{\bar{y}}/\bar{y}$ for sizes of both species, per cent		5.1

* Significant at 5 per cent level.
** Significant at 1 per cent level.

Table XII. Analysis of variance of yield in grams from ten rates of seeding of each of two mustard species grown at Bozeman, Harve, and Sunburst.

Sources of Variation	Degrees of Freedom	Mean Square for Yield in Grams Per plot		
		Bozeman	Harve	Sunburst
Species of Mustard	1	163895.5**	16936.2**	5152.0
Error (A)	3	16006.5	416.1	1742.9
Seeding Rates	9	16572.7**	718.8**	227.0
Seeding Rates x species	9	1440.4	218.4**	125.9
Error (B)	54	1860.1	14.8	119.6
$s_{\bar{y}}$ for rates of both species		91.4	8.2	-
$s_{\bar{y}}$ for rates within species		129.1	11.5	-
$s_{\bar{y}}/\bar{y}$ for rates of both species, per cent		4.9	2.5	4.9
$s_{\bar{y}}/\bar{y}$ for rates within species, per cent		7.0	3.5	6.9

* Significant at 1 per cent level.
** Significant at 5 per cent level.

Table XIII. Complex analysis of variance of yield in grams, and seed size index and test weight of the harvested crop from ten rates of seeding of each of two mustard species grown at ten locations.

Sources of Variation	Degrees of Freedom	Mean Square from the Analysis of Three Locations: Yield in Grams	Seed Size Index	Test Weight
Locations	2	1542989.9**	2126126.8**	215.40**
Error A	9	1940.6	249.8	0.36
Species of Mustard	1	122718.0	1255417.4**	178.90**
Species x Locations	2	31632.8	29486.2**	89.40**
Error B	9	6043.5	1037.8	0.40
Rates of Seeding	9	8689.1**	198.2	1.50**
Rates x Locations	18	4415.8**	455.9	3.10**
Rates x Species	9	625.7	939.4**	1.70**
Rates x Species x Location	18	599.0	291.6	1.20*
Error C	162	707.2	213.6	0.57

	Yield in Grams	Seed Size Index	Test Weight
$s_{\bar{y}}$ for rates of both species	32.6	-	0.15
$s_{\bar{y}}$ for rates within species	46.0	4.2	0.22
$s_{\bar{y}/\bar{y}}$ for rates of both species, per cent	3.7	1.3	0.3
$s_{\bar{y}/\bar{y}}$ for rates within species, per cent	5.2	1.8	0.4

* Significant at 1 per cent level.
** Significant at 5 per cent level.

Table XIV. Correlation and regression coefficients for stand (x) and yield (y).

Name of Experiments and Location	Relation of Number of Plants to Yield					
	Oriental Yellow Mustard			Yellow Mustard		
	r	b_{yx}	$\bar{Y}-(b_{yx})\bar{x}$	r	b_{yx}	$\bar{Y}-(b_{yx})\bar{x}$
1. Seed size experiment planted with constant number of seed per unit area1/ Bozeman	0.37	11.20	617.6	.57**	29.80	-1133.2
2. Seed size experiment planted with a constant weight of seed per unit area1/ Bozeman	-0.178	-2.70	1612.6	0.816**	1.18	1747.8
3. Rate of seeding trial-Bozeman	0.564**	3.90	1701.0	0.675**	8.40	980.8
4. Seed size experiment planted with constant number of seed per unit area1/ Havre	0.271	1.15	337.0	0.239	0.95	187.1
5. Rate of seeding trial-Havre	0.664**	1.61	237.9	0.597**	2.10	116.1
All 5 experiments combined	0.419**	3.50	951.0	0.53**	6.40	605.7

1/ Coefficients freed of seed size effect.

* Significant at 5 per cent level.
** Significant at 1 per cent level.

Considering the effect of seed size on yield of two mustard species at all three locations, it will be noted that there is a significant influence of seed size planted on yield. This effect of seed size planted is not consistant at all three locations as previously discussed. Duncan's multiple range test indicates that at least three size categories influence yields, with the largest size yielding the most, when equal numbers of seed are planted.

At Bozeman, when seeding is at a constant weight per unit area, yield differences due to seed sizes planted are not significant. This indicates at least a partial compensation of the seed size effect previously observed by planting more seed per unit area. Determining seeding rate by a constant weight provides a greater number of smaller sized seed than larger sized seed and, ultimately, more nearly comparable stands. This compensation in stand is much more pronounced for oriental yellow mustard than yellow mustard.

The effect of seeding rate is pronounced and highly significant at Bozeman and Havre, but non-significant at Sunburst. Examination of the yield data from Bozeman, Havre and Sunburst and an average of all three locations reveals that the higher seeding rates produced higher yields. At Havre, yield due to seeding rates is significantly different for the two mustard species. Oriental yellow mustard appears to reach a maximum yield at a somewhat lower seeding rate than yellow mustard. This may be due to differences in maturity of the two mustard species or to differences in seed size. Throughout these trials, the dissimilarity of response of these two mustard species may be noted.

The reaction of yield to stand indicates a significant positive correlation for both species. There is considerable variation in degree of relationship within the individual experiments. One interesting deviation may be noted for the oriental yellow mustard in the experiment involving seeding the various seed sizes at a constant weight per acre. We find no significant correlation, actually a negative correlation between number of plants and yield. It should be remembered that the correlation has been freed of the relationship of stand to yield associated with seed size. This observed relationship may be due to the presence of an adequate stand for a given area, obtained from the smaller seed by this method of planting. This follows the rule of marginal utility or marginal productivity. In other words, the seeding rate used for at least some seed sizes of oriental yellow had reached a stage where marginal utility had decreased.

D. Factors Influencing Seed Size Index: Mean values for the seed size index of the harvested crop of two mustard species as influenced by species, seed sizes, location, and rates of seeding are recorded in Tables XV and XVI. The analysis of variance of seed size index separately for locations and also the complex analysis for three locations combined is reported in Tables XIII and XVII, XVIII, and XIX. Correlation coefficients and regression coefficients for seed size index and number of plants were determined and are reported in

Table XV. Average Seed Size Index of the harvested crops from six different sizes of each of two mustard species grown at one rate of seeding at Havre and Sunburst and at two rates of seeding at Bozeman.

Species of Mustard	Size No. Sown	Average Seed Size Index of Harvested Crop When the Seeding Rate of Viable Seed Is*				
		12 Per Square Foot				5 Pounds Per Acre
		Bozeman	Havre	Sunburst	Average	Bozeman
Oriental Yellow	1	304	75	142	174	321a
	2	285	51	128	155	312ab
	3	282	58	126	155	313ab
	4	268	49	118	145	311ab
	5	279	40	123	147	300b
	6	260	33	106	133	304b
	Average	280	51	124	152	310
Yellow	1	500	171	285	319	478bc
	2	472	124	256	284	465c
	3	480	142	264	295	481bc
	4	476	130	232	279	480bc
	5	468	100	242	270	487ab
	6	453	114	232	266	498a
	Average	475	130	252	286	482
Average for Both Species	1	402a	123a	214a	246a	400
	2	378bc	88bcd	192bc	219bc	388
	3	381ab	100b	195b	225b	397
	4	272bc	90bc	175de	212cd	396
	5	374bc	70d	182cd	209de	394
	6	356c	74cd	169e	200e	401
	General Mean	377	91	188	219	396

* Values for a species - location followed by the same letter are not significant from each other at the 5 per cent level.

Table XVI. Average seed size index of the harvested crop from ten seeding rates for each of two mustard species grown at Bozeman, Harve and Sunburst.

Species of Mustard	Seeding Rate in Pounds Per Acre	Average Seed Size Index of the Harvested Crop* Bozeman	Havre	Sunburst	Average
Oriental Yellow	1	334a	28	148a	170a
	2	316a	32	106bc	151b
	3	319a	33	116b	156b
	4	317a	38	104bc	153b
	5	319a	55	110bc	161ab
	6	324a	35	92bc	150b
	7	318a	47	99bc	155b
	8	320a	44	89c	151b
	9	312a	46	104b	154b
	10	316a	48	96bc	153b
	Average	319	41	106	155
Yellow	1	478c	120	251a	283b
	2	489bc	139	256a	295ab
	3	493abc	138	256a	296ab
	4	507ab	146	260a	304a
	5	503ab	152	260a	305a
	6	497abc	156	266a	306a
	7	515a	137	257a	303a
	8	499abc	155	262a	305a
	9	511ab	146	265a	307a
	10	488bc	147	262a	299a
	Average	498	144	260	300
Average for Both Species	1	406	74c	199	226
	2	402	85bc	181	223
	3	406	86bc	186	226
	4	412	92ab	182	229
	5	411	104a	185	233
	6	410	95ab	179	228
	7	417	92ab	178	229
	8	409	99ab	176	228
	9	412	96ab	184	231
	10	402	97ab	179	226
	General Means	409	92	183	228

* Values for a species-location followed by the same letter are not significant from each other at the 5 per cent level.

Table XVII. Analysis of variance of "seed size index" of the harvested crops grown from six different seed sizes of each of two mustard species grown at one rate of seeding at Havre and Sunburst and at two rates of seeding at Bozeman.

Sources of Variation	Degrees of Freedom	Mean Square for Seed Size Index of Harvested Crop When Seeding Rate of Viable Seed is			
		12 Per Square Foot			5 Pounds Per Acre
		Bozeman	Havre	Sunburst	Bozeman
Species of Mustard	1	455566.9**	74497.5**	196352.0**	352775.5**
Error A	3	1025.8	285.1	50.3	87.3
Seed Size Planted	5	1416.6*	2956.5**	2047.9**	164.2
Error B	15	436.4	267.7	124.1	87.1
Size x Species	5	616.1	290.1	217.9	529.4**
Error C	15	215.3	215.8	119.5	103.6
$s_{\bar{y}}$ for sizes of both species		7.39	5.78	3.9	-
$s_{\bar{y}}$ for sizes within species		7.33	7.34	5.45	5.08
$s_{\bar{y}}/\bar{y}$ for sizes of both species, %		1.96	6.30	2.07	0.83
$s_{\bar{y}}/\bar{y}$ for size within species, %		1.94	8.01	2.90	1.30

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

Table XVIII. Complex analysis of variance of "Seed size index" of the harvested crop from six different planted seed sizes of each of two mustard species grown at three locations and planted at a rate of 12 viable seed per square foot.

Source of Variation	Degrees of Freedom	Mean Square
Locations grown	2	1020910.8**
Error (A)	6	549.4
Species of Mustard	1	646684.0**
Species x Location	2	41111.2**
Error (B)	9	288.2
Seed Size Planted	5	6212.8**
Seed Size x Location	10	260.2
Error (C)	45	241.3
Species x Size	5	362.1
Species x Size x Location	10	241.9
Error (D)	45	214.5
$S_{\bar{y}}$ for sizes of both species		3.17
$S_{\bar{y}}/\bar{y}$ for sizes of both species, per cent		1.44

* Significant at the 5 per cent level.
** Significant at the 1 per cent level.

Table XIX. Analysis of variance of "seed size index" of the harvested crop grown from ten rates of seeding of each of two mustard species at Bozeman, Havre, and Sunburst.

Sources of Variation	Degrees of Freedom	Mean Square for "seed size index" of Harvested Crop		
		Bozeman	Havre	Sunburst
Species of Mustard	1	636531.2**	211665.3**	466193.1**
Error (A)	3	2872.4	140.5	100.8
Seeding Rate	9	136.3	586.9**	336.6
Rates of Seeding x Species	9	499.9*	173.7	848.9**
Error (B)	54	221.0	166.3	253.4

$s_{\bar{y}}$ for rates of both species	-	4.65	-
$s_{\bar{y}}$ for rates within species	7.43	6.45	7.95
$s_{\bar{y}}/\bar{y}$ for rates of both species, per cent	1.3	4.9	3.1
$s_{\bar{y}}/\bar{y}$ for rates within species, per cent	1.8	7.0	4.3

* Significant at 1 per cent level.
** Significant at 5 per cent level.

Table XX. Correlation and regression coefficients for stand (x) and "seed size index" (y).

Name of Experiment and Location	Relation of "seed size index" to number of plants					
	Oriental Yellow Mustard			Yellow Mustard		
	r	b_{yx}	$\bar{Y}-b_{yx}(\bar{x})$	r	b_{yx}	$\bar{Y}-b_{yx}(\bar{x})$
1. Seed size experiment-planted with constant number of seed per unit area-Bozeman 1/	0.030	0.036	276.9	0.322	0.817	398.2
2. Seed size experiment-planted with a constant weight of seed per unit area-Bozeman 1/	0.599**	0.366	261.7	0.282	-0.192	465.7
3. Rate of seeding trial-Bozeman	0.229	0.210	288.5	0.250	0.190	484.7
4. Seed size experiment-planted with constant number of seed per unit area-Havre 1/	0.270	0.285	28.2	0.166	0.136	121.4
5. Rate of seeding trial-Havre	0.801**	0.327	112.5	0.235	0.172	133.8
All five experiments combined	0.27**	0.235	171.0	0.234**	0.185	340.0

1/ Coefficients freed of seed size effect.

* Significant at 5 per cent level.
** Significant at 1 per cent level.

Table XX . These values were determined for the seed size experiments after eliminating the effects of seed size.

Results indicate a significant influence of seed size planted on the seed size of the harvested crop at all locations and at both rates of seeding. Differences are the same for both species when equal numbers of seed are planted. When equal weight of seed is planted, the influence of seed size planted on seed size index is not the same for both species. A complex analysis of variance of the seed size index obtained on seed harvested from the three locations planting equal number of seed per unit area indicates that location influences seed size index but not each species equally. Seed size index is influenced equally by size of seed planted at all three locations. Application of Duncan's multiple range test to the data results in an indication that, when an equal number of seed are planted, the largest size seed produces the seed with highest seed size index.

The ten different seeding rates created significantly different seed size indexes at all three locations. At Bozeman, seeding rate did not influence the seed size index of oriental yellow mustard whereas increasing rates of seeding resulted in an increased seed size index for yellow mustard.

At Sunburst the situation was reversed with seeding rate having no influence on the yellow mustard seed size index, but it did have an influence on the seed size index of oriental yellow mustard. Seeding rate influenced the seed size index for both types of mustard at Havre. These observations are confirmed by the significant rate x location interactions reported in Table XIII.

One interesting observation is the generally significant positive correlations between number of plants and seed size. This may be due to the indeterminate growth habit of mustard. Bloom can continue for an indefinite period under favorable conditions, but it stops earlier if conditions are not favorable, and the seed matures. Flowering of mustard is quite sensitive to environmental conditions while the maturing plant is not so sensitive. This could explain the larger seed size index of plants under the more intense competition of thicker stands.

E. <u>Factors Influencing Test Weight</u>: Mean values for test weight (in pounds per bushel) of the harvested crop of two mustard species as influenced by species, seed sizes, locations, and rate of seeding are recorded in Tables XXI and XII. Analysis of variance of test weight separately for the locations and also the complex analysis for the three locations combined are reported in Tables XIII, XXIII, XXIV, and XXV. Correlation coefficients and regression coefficients for test weight and number of plants are reported in Tables XXVI. These values for the seed size experiments were determined after eliminating the effects of seed size.

No effect of seed size planted on test weight was observed at Havre. At Bozeman and Sunburst when equal number of seeds were planted, the interaction seed size planted x species was significant at the 5 per cent level. When a constant weight of seed was planted,

Table XXI. Average test weight, in pounds per bushel, of the harvested crops from six different sizes of each of two mustard species grown at one rate of seeding at Havre and Sunburst and at two rates of seeding at Bozeman.

Species of Mustard	Size No.	Average Test Weight in Pounds Per Bushel of Harvested Crop When Seeding Rate of Viable Seed Is*				
		12 Per Square Foot				5 pounds Per Acre
		Bozeman	Havre	Sunburst	Average	Bozeman
Oriental Yellow	1	51.8a	53.9	53.8b	53.2	52.0ab
	2	51.2b	53.1	54.8a	53.0	51.8ab
	3	51.2b	53.4	54.4ab	53.0	51.1b
	4	51.4ab	53.2	54.9a	53.2	50.4b
	5	51.0bc	53.6	54.7a	53.1	52.8a
	6	50.6c	53.7	54.7a	53.0	53.1a
	Average	51.2	53.5	54.6	53.1	51.9
Yellow	1	55.7a	55.3	57.2a	56.1	54.5a
	2	55.6a	55.4	57.4a	56.1	54.5a
	3	55.3a	54.9	57.0ab	55.7	54.5a
	4	55.7a	55.4	56.4b	55.8	55.1a
	5	55.6a	55.9	56.7a	56.1	54.6a
	6	55.7a	55.4	57.5a	56.2	54.8a
	Average	55.6	55.4	57.0	56.0	54.7
Average for Both Species	1	53.8	54.6	57.5	55.3	53.2bc
	2	53.4	54.2	56.1	54.6	53.2bc
	3	53.2	54.2	55.7	54.4	52.8c
	4	53.6	54.3	55.6	54.5	52.8c
	5	53.3	54.8	55.7	54.6	53.7ab
	6	53.2	54.6	56.1	54.6	54.0a
	General Mean	53.4	54.4	56.1	54.6	53.3

* Values for a species - location followed by the same letter are not significant from each other at the 5 per cent level.

Table XXII. Average Test Weight in pounds per bushel of harvested crop from ten seeding rates in each of two mustard species grown at Bozeman, Havre and Sunburst.

Species of Mustard	Seeding Rate in Pounds Per Acre	Average test Weight in Pounds Per Bushel of Harvested Crop*			
		Bozeman	Havre	Sunburst	Average
Oriental Yellow	1	53.8a	52.0ab	52.8	52.9ab
	2	53.8a	51.4bc	53.0	52.7ab
	3	54.0a	52.5ab	53.0	53.2a
	4	53.4a	52.5ab	52.9	52.9ab
	5	53.0a	50.5c	53.5	52.3b
	6	53.5a	51.4bc	52.5	52.5ab
	7	53.6a	53.0a	52.6	53.1a
	8	53.0a	52.8ab	52.1	52.6ab
	9	53.3a	52.9a	53.0	53.1a
	10	53.0a	52.8ab	52.6	52.8ab
	Average	53.4	52.2	52.8	52.8
Yellow	1	56.5abc	49.6d	56.8	53.4bcd
	2	55.9bc	51.0bcd	54.8	53.9ab
	3	56.3abc	49.8cd	55.8	54.0d
	4	57.1a	51.1bc	55.5	54.6abcd
	5	56.9ab	51.1bc	56.2	54.7abc
	6	55.7c	51.2b	55.4	54.1cd
	7	56.6abc	52.4ab	55.8	54.9ab
	8	56.5abc	53.0a	55.5	55.0ab
	9	56.5abc	52.7a	55.3	54.8abc
	10	56.9ab	52.8a	55.5	55.1a
	Average	56.5	51.5	55.6	54.5
Average for Both Species	1	54.2	50.8d	54.8	53.6abc
	2	54.9	51.2cd	53.9	53.3c
	3	55.2	51.2cd	54.4	53.6abc
	4	55.3	51.8abc	54.2	53.8ab
	5	54.9	50.8d	54.9	53.5bc
	6	54.6	51.3cd	53.9	53.3c
	7	55.1	52.7ab	54.2	54.0a
	8	54.7	52.9a	53.8	53.8ab
	9	54.9	52.8a	54.2	53.9ab
	10	54.9	52.8a	54.0	53.9ab
	General Mean	54.9	51.8	54.2	53.6

* Values for a species - location followed by the same letter are not significant from each other at the 5 per cent level.

Table XXIII. Analysis of variance of test weights, in pounds per bushel, of the harvested crops grown from six different seed sizes of each of two mustard species grown at one rate of seeding at Havre and Sunburst and at two rates of seeding at Bozeman.

Sources of Variation	Degrees of Freedom	Mean Square for Test Weight in Lbs. Per Bushel of Harvested Crop When Seeding Rate of Viable Seed is			
		12 Per Square Foot			5 Pounds Per Acre
		Bozeman	Havre	Sunburst	Bozeman
Species of Mustard	1	228.83**	43.50**	75.80**	93.20**
Error A	3	0.173	0.06	0.26	0.66
Seed Sizes Planted	5	0.40	0.44	0.52	1.88*
Error B	15	0.19	0.38	0.24	0.50
Size x Species	5	0.38*	0.32	0.90*	2.54**
Error C	15	0.13	0.20	0.26	0.53
$s_{\bar{y}}$ for sizes of both species		-	-	-	0.250
$s_{\bar{y}}$ for sizes within species		0.18	-	-	0.364
$s_{\bar{y}}/\bar{y}$ due to size of both species, %		0.3	0.40	0.3	0.5
$s_{\bar{y}}/\bar{y}$ due to size within species, %		0.3	0.40	0.4	0.7

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

Table XXIV. Complex analysis of variance of test weight in pounds per bushel of the harvested crop from six different seed sizes of each of two mustard species grown at three locations when planted at a rate of 12 viable seed per square foot.

Source of Variation	Degrees of Freedom	Mean Square
Locations	2	67.80**
Error (A)	6	0.36
Species of Mustard	1	308.60**
Species x Location	2	19.75**
Error (B)	9	0.16
Seed Size Planted	5	0.20
Seed Size x Location	10	0.57*
Error (C)	45	0.27
Species x Sizes	5	0.28
Species x Size x Location	10	0.77**
Error (D)	45	0.18
$s_{\bar{y}/\bar{y}}$ for sizes of both species		0.20
$s_{\bar{y}/\bar{y}}$ for sizes within species		0.23

* Significant at 5 per cent level.
** Significant at 1 per cent level.

Table XXV. Analysis of variance of test weight in pounds per bushel, of the harvested crop grown from ten rates of seeding of each of two mustard species at Bozeman, Havre, and Sunburst.

Sources of Variation	Degrees of Freedom	Mean Square of Test Weight in Pounds Per Bushel of Harvested Crop		
		Bozeman	Havre	Sunburst
Species of Mustard	1	185.50**	10.20**	162.20**
Error (A)	3	1.00	0.30	0.50
Seeding Rate	9	0.40	6.03**	1.10
Rates of Seeding x Species	9	1.00*	2.40*	0.73
Error (B)	54	0.48	0.47	0.77
$s_{\bar{y}}$ for rates of both species		-	0.24	-
$s_{\bar{y}}$ for rates within species		0.35	0.34	-
$s_{\bar{y}}/\bar{y}$ for rates of both species, per cent		0.5	0.5	0.6
$s_{\bar{y}}/\bar{y}$ for rates within species, per cent		0.6	0.7	0.8

* Significant at 5 per cent level.
** Significant at 1 per cent level.

differences in test weight due to size of seed planted were significant at 5 per cent level and differences due to interaction of species and size of seed planted were significant at the 1 per cent level.

The complex analysis revealed significant differences in test weight due to locations and species. The species did not have the same relative test weight at all locations. The location x seed size planted x species of mustard interaction was also significant. This indicates that test weight differences due to seed size planted are influenced by location. The only differences noted were in oriental yellow mustard.

No significant differences in test weight due to differences in seeding rate were observed at Sunburst, though differences due to species are evident. Significant differences in test weight due to rates of seeding were observed at Bozeman and at Havre. These differences, where only the test weight of yellow mustard was influenced, seem to be randomly distributed at Bozeman. At Havre, the higher rates of seeding tend to produce the higest test weight seed.

Positive significant correlation coefficients between stand and test weight were observed for yellow mustard. Correlation coefficients of stand and test weight for individual experiments reveal a variation from significant negative to significant positive correlation coefficients in oriental yellow mustard.

F. Factors Influencing Yield Components: Data for average number of pods on the terminal raceme, number of seed per pod, weight per 100 seed in grams and number of plants per unit area as obtained from two seed size experiments and one rate of seeding experiment at Bozeman are reported in Tables XXVI to XXIX. Analysis of variance of these data are reported in Tables XXX to XXXII. Correlation coefficients for the different components of yield and corresponding regression coefficients were determined for the three experiments separately and from the combined data and are reported in Tables XXXIII and XXXIV and Appendix Tables I to IX. These values for correlation and regression coefficients were determined for the seed size experiments after eliminating the effect of seed size.

The results indicate signficant variation due to sizes of seed, species, and seeding rates. Each component is directly influenced by the increments used and as such, we shall deal with them separately. Factors affecting stand have been discussed in detail earlier. We shall discuss here the remaining three factors; namely, number of pods per terminal raceme, number of seed per pod, and weight of seeds per pod.

(a) Factors affecting the number of pods on the terminal raceme: Results of the analysis of variance and the correlation and regression coefficients between stand and number of pods per terminal raceme indicate that when equal numbers of viable seed are planted, there is apparently no significant differences due to size of seed planted. One significant observation is a negative correlation between stand and number of pods, as stand increased the number of pods on the central raceme declined, as might be expected. Variation in number

Table XXVI. Correlation and regression coefficients of stand (x) and test weights (y).

Name of Experiments and Location	Relation of Test Weight in Pounds Per Bushel to Number of Plants					
	Oriental Yellow Mustard			Yellow Mustard		
	r	b_{yx}	$\bar{Y}-b_{yx}(\bar{x})$	r	b_{yx}	$\bar{Y}-b_{yx}(\bar{x})$
1. Seed size experiment planted with constant number of seed per unit area 1/ Bozeman	0.184	0.00578	51.25	0.0783	0.0040	55.22
2. Seed size experiment planted with a constant weight of seed per unit area 1/ Bozeman	-0.277	-0.00930	53.12	0.6190**	0.0303	52.80
3. Rate of seeding trial - Bozeman	-0.429**	-0.00520	53.50	0.1120	0.0028	56.30
4. Seed size experiment planted with constant number of seed per unit area 1/	0.264	0.00980	52.80	0.0297	0.0008	55.40
5. Rate of seeding trial- Havre	0.342*	0.01260	51.10	0.5380**	0.0298	49.75
All experiments combined	-0.102	-0.00212	52.7	0.3386**	0.0132	45.00

1/ Coefficients freed of seed size effect.

* Significant at 5 per cent level.
** Significant at 1 per cent level.

Table XXVII. Average yield component measurements obtained from six different seed sizes of each of two mustard species grown at Bozeman when the seeding rate was 12 viable seed per square foot.

Species of Mustard	Sizes	Average Yield Component Measurements* Pods Per Terminal Raceme	Seed Per Pod	Weight of 100 Seed	Plants Per 16 Square Feet
		No.	No.	Grams	No.
Oriental Yellow	1	39.1	15.3	0.38	104a
	2	38.3	13.1	0.33	88bc
	3	38.4	15.1	0.33	104a
	4	34.8	15.6	0.33	92b
	5	38.2	14.6	0.34	81bc
	6	36.0	14.5	0.34	52d
	Average	37.5	14.7	0.34	87
Yellow	1	55.9	5.6	0.70	106a
	2	52.4	5.3	0.68	106a
	3	50.7	5.6	0.66	109a
	4	49.2	5.6	0.67	92b
	5	53.8	5.8	0.67	86b
	6	48.3	5.5	0.64	65c
	Average	51.7	5.6	0.67	94
Average of Both Species	1	47.5	10.4	0.54	105ab
	2	45.4	9.2	0.50	97abc
	3	44.6	10.4	0.50	106a
	4	42.0	10.6	0.50	92abc
	5	46.0	10.2	0.50	84c
	6	42.2	10.0	0.49	58c
	General Mean	44.6	10.1	0.50	90

* Values for a species - component measurements followed by the same letter are not significant from each other at the 5 per cent level of significance.

Table XXVIII. Average yield component measurements obtained from six different seed sizes of each of two mustard species grown at Bozeman when the seeding rates was five pounds per acre.

Species of Mustard	Sizes	Average Yield Component Measurements* Pods Per Terminal Raceme	Seed Per Pod	Weight of 100 seed	Plants Per 16 Square Feet
		No.	No.	Grams	No.
Oriental	1	42.1ab	15.6	0.36	100c
	2	41.2abc	13.5	0.36	103c
	3	40.5abcd	14.2	0.38	130b
	4	43.8a	14.5	0.40	144b
	5	37.8bcd	15.0	0.41	146b
	6	36.2d	14.2	0.38	169a
	Average	40.1	14.5	0.38	132.0
Yellow	1	59.0ab	5.6	0.73	96b
	2	61.5a	5.3	0.74	98b
	3	55.2bc	5.6	0.74	86c
	4	51.2cde	6.0	0.69	105a
	5	53.6cd	5.4	0.72	73e
	6	47.8e	5.8	0.73	81d
	Average	54.7	5.6	0.72	90.0
Average of Both Species	1	50.6ab	10.6	0.54	98bcd
	2	51.4a	9.4	0.55	100b
	3	47.8bc	9.9	0.56	108bcd
	4	47.5bcd	10.2	0.53	124a
	5	45.7cde	10.2	0.56	110d
	6	42.0e	10.0	0.56	125bc
	General Mean	47.5	10.0	0.55	111

* Values for a species - component measurements followed by the same letter are not significant from each other at the 5 per cent level of significance.

Table XXIX. Average yield component measurements obtained from ten seeding rates of each of two mustard species grown at Bozeman.

Species of Mustard	Rate of Seeding in Pounds Per Acre	Average Yield Component Measurements*			
		Pods Per Terminal Raceme	Seed Per Pod	Weight per 100 Seed	Plants Per 16 Square Feet
		No.	No.	Grams.	No.
Oriental Yellow	1	49.2ab	16.0	0.35	28j
	2	49.8a	16.5	0.37	44i
	3	44.0abc	16.8	0.36	58h
	4	44.2abc	17.1	0.38	66g
	5	41.6bcde	16.8	0.38	112f
	6	43.4bcd	16.2	0.36	120e
	7	39.9cde	16.2	0.36	132d
	8	37.1e	16.3	0.38	154c
	9	38.3de	15.6	0.38	172b
	10	38.6de	15.9	0.39	187a
	Average	42.3	16.4	0.37	107
Yellow	1	54.9a	5.4	0.74	18f
	2	56.1a	5.8	0.75	35e
	3	57.6a	5.8	0.68	40e
	4	58.4a	5.8	0.71	66d
	5	54.5	5.6	0.74	67d
	6	56.9a	5.4	0.72	79c
	7	57.1a	6.2	0.70	83c
	8	55.5a	5.6	0.71	99b
	9	53.0a	6.0	0.74	98b
	10	53.6a	6.0	0.69	112a
	Average	55.8	5.8	0.72	70
Average of Both Species	1	50.6ab	10.7	0.54	23j
	2	53.0	11.2	0.56	40i
	3	50.8ab	11.3	0.52	49h
	4	51.3ab	11.4	0.55	66g
	5	48.0bc	11.2	0.56	90f
	6	50.2b	10.8	0.54	100e
	7	48.5bc	11.2	0.53	108d
	8	46.3c	10.9	0.54	126c
	9	45.7c	10.8	0.56	135b
	10	46.1c	10.9	0.54	154a
	General Means	49.0	11.0	0.54	89

* Values for a species - component measurements followed by the same letter are not significant from each other at 5 per cent level of significant.

Table XXX. Analysis of variance of yield components obtained from six different seed sizes of two mustard species grown at a seeding rate of 12 viable seed per square foot at Bozeman.

Sources of Variation	Degrees of Freedom	Mean Square for Yield Components in Respective Units			
		Number of Pods on Main Raceme	Number of Seed Per Pod	Weight of 100 Seed in Grams	Number of Plants Per 16 Square Feet
Species of Mustard	1	2441.00**	120.50**	1.300**	638.0
Error A	3	59.80	8.10	0.005	273.9
Seed Size Planted	5	38.30	11.96	0.003	2360.5**
Error B	15	26.70	3.46	0.002	217.4
Size x Species	5	6.54	7.10	0.001	267.4**
Error C	15	5.64	2.60	0.001	53.2
$s_{\bar{y}}$ due to sizes in both species		-	-	-	5.21
$s_{\bar{y}}$ due to size within species		-	-	-	3.65
$s_{\bar{y}/\bar{y}}$ due to size in both species, per cent		4.1	6.5	3.2	5.8
$s_{\bar{y}/\bar{y}}$ due to size within species, per cent		2.6	7.9	3.7	4.1

* Significant at 5 per cent level.
** Significant at 1 per cent level.

Table XXXI. Analysis of variance of yield components obtained from six different seed sizes of two mustard species at a seeding rate of 5 pounds of viable seed per acre, at Bozeman.

Sources of Variation	Degrees of Freedom	Mean Square for Yield Components in Respective Units: Number of Pods On Main Raceme	Number of Seed Per Pod	Weight of 100 Seed in Grams	Number of Plants Per 16 Square Feet
Species of Mustard	1	2504.1*	949.60**	1.394**	21168.0*
Error A	3	82.1	6.90	0.003	1432.1
Seed Size Planted	5	94.1**	1.30	0.001	1041.2*
Error B	15	9.7	1.70	0.002	250.7
Size x Species	5	37.7**	1.02	0.003	2318.7**
Error C	15	7.6	1.67	0.017	186.1
$s_{\bar{y}}$ due to sizes in both species		1.10	-	-	5.59
$s_{\bar{y}}$ due to sizes within species		1.38	-	-	6.82
$s_{\bar{y}}/\bar{y}$ due to sizes in both species, per cent		2.3	4.6	3.1	5.0
$s_{\bar{y}}/\bar{y}$ Due to sizes within species, per cent		2.9	6.4	3.8	6.2

* Significant at 5 per cent level.
** Significant at 1 per cent level.

Table XXXII. Analysis of variance of yield components obtained from ten seeding rates of each of two mustard species grown at Bozeman.

Sources of Variation	Degrees of Freedom	Mean Square for Yield Components in Respective Units: Pods In Main Raceme in Number	Seeds Per Pod In Number	Weight of 100 Seed in Grams	Plants Per 16 Square Feet in No.
Species of Mustard	1	3628.9*	2246.10**	2.370**	28087.5**
Error A	3	110.6	3.90	0.003	379.9
Rates of Planting	9	49.2**	0.50	0.002	14775.1**
Rates x Species	9	26.1*	0.70	0.002	1464.4**
Error B	54	11.7	0.87	0.002	29.8
$s_{\bar{y}}$ for rates in both species		1.15	-	-	1.9
$s_{\bar{y}}$ for rates within species		1.70	-	-	2.7
$s_{\bar{y}}/\bar{y}$ for rates in both species, per cent		2.3	2.9	2.6	2.2
$s_{\bar{y}}/\bar{y}$ for rates within species, per cent		3.5	4.3	3.6	3.1

* Significant at 5 per cent level.
** Significant at 1 per cent level.

Table XXXIII. Relation Between Yield and Yield Components in Oriental Yellow Mustard.

	ORIENTAL YELLOW MUSTARD			
	Pods Per Terminal Raceme	Seed Per Pod	Weight of 100 Seed	Plants Per 16 Square Feet
	No.	No.	Gram	No.
<u>Values of Correlation Coefficients-r</u>				
1. Yield in pounds per acre	0.176	0.036	0.312**	0.419**
2. Number of pods per central raceme	-	-0.005	0.156	-0.533**
3. Number of seed per pod		-	-0.328**	-0.013
4. Weight of 100 seed in grams			-	0.047
5. Number of plants per unit area				-
<u>Values of Regression Coefficients</u> b_{yx}				
1. Yield in pounds per acre	10.600	-5.890	3243.00**	3.500**
2. Number of pods	-	-0.002	0.0001	-0.666**
3. Number of seed per pod		-	-0.005**	-0.133
4. Weight of 100 seed in grams			-	0.00002
5. Number of plants per unit area				-
<u>Values of Constant</u> $\bar{Y} - b_{yx}\bar{X}$				
1. Yield in pounds per acre	1500.90	1838.30	738.800	951.000
2. Number of pods	-	15.47	0.330	47.550
3. Number of seed per pod		-	0.447	15.433
4. Weight of 100 seed in grams			-	0.349
5. Number of plants per unit area				-

* Significant at 5 per cent level.

Table XXXIV. Relation Between Yield and Yield Components in Yellow Mustard.

	YELLOW MUSTARD			
	Pods Per Terminal Raceme	Seed Per Pod	Weight of 100 Seed	Plants Per 16 Square Feet
	No.	No.	Grams	No.
Values of Correlation Coefficients-r				
1. Yield in pounds per acre	0.061	0.098	0.138	0.530**
2. Number of pods per central raceme	-	-0.006	0.048	-0.047
3. Number of seed per pod		-	-0.047	0.004
4. Weight of 100 seed in grams			-	0.038
5. Number of plants per unit area				-
Values of Regression Coefficeints, b_{yx}				
1. Yield in pounds per acre	2.610	19.500	892.80	6.400**
2. Number of pods	-	-0.001	0.0003	-0.016
3. Number of seed per pod		-	0.005	0.0003
4. Weight of 100 seed in grams			-	-0.0001
5. Number of plants per unit area				-
Values of Constant $Y-b_{yx}X$				
1. Yield in pounds per acre	1530.00	1561.60	1041.70	605.70
2. Number of pods	-	5.73	0.689	55.710
3. Number of seed per pod		-	0.732	5.630
4. Weight of 100 seed in grams			-	0.777
5. Number of plants per unit area				-

* Significant at 5 per cent level.

of pods for the species is significant at the one per cent level. When seed of the various seed size categories is planted at a constant weight per unit area, we find a definite influence of seed size on number of pods and the variations in pod number due to seed size planted are not the same for the two species (Table XXXI). In this experiment, we find the negative correlation to be significant at the one per cent level in oriental yellow mustard but nonsignificant in yellow mustard (Appendix Table I).

In the rate of seeding trial, we find a significant variation in number of pods per terminal raceme due to species as recorded for the two seed size experiments. In addition, there is a significant influence of seeding rates on number of pods per central raceme which is not the same for both species.

There is significant correlation between stand and pods for oriental yellow mustard but no significant correlation for yellow mustard (Appendix Table I).

It may be observed that the results of the rate of seeding trial are similar to results obtained in the seed size experiments planted with a constant weight of seed per unit area. In both the experiments variation in number of plants per unit area in oriental yellow mustard, either due to sizes or due to rates, is greater and in a more consistent order in oriental yellow mustard than in the yellow mustard. This may account for the significant relationship of stand to number of pods in oriental yellow mustard and an apparent lack of relationship in yellow mustard.

Greater variation in stand in these latter two trials as compared to the seed size trial planted with equal number of seeds may be the reason for greater variation in number of pods per terminal raceme.

Considering oriental yellow mustard, it may be concluded that, although the central raceme is the earliest and first to mature, the number of pods produced on this raceme is very sensitive to plant population differences, or stand. Oriental yellow mustard is more sensitive than yellow mustard with reference to pods per central raceme. There seems to be a depressing effect on number of pods as the stand increases beyond approximately 110 plants per sixteen square feet. The highest average number of plants per sixteen square feet recorded for yellow mustard was 112. It does not appear that plant populations of less than this have any marked effect on the number of pods on the central raceme of this species.

(b) Factors affecting the number of seeds per pod: Results reported in Tables XXVII to XXXIV and Appendix Tables II and III reveal one significant result - variation in number of seeds per pod due to species is significant at the one per cent level. No significant changes are brought about by the environmental factors such as rates of seeding or size of seed planted, directly or indirectly.

Correlation and regression coefficients for stand and number of seeds per pod or number of pods per terminal raceme and number of seeds per pod indicate no significant relationships. At the stand levels studied, 28-187 plants per sixteen square feet for oriental yellow mustard and from 18-112 for yellow mustard, there would appear to be no consistent relationship between stand and number of seeds per pod. (Table XXXIII, XXXIV and Appendix Table II).

(c) Factors affecting weight of seed in grams: Results indicate that weight of seed is not influenced by stand or size of seed planted. Weight of seed is significantly different for the species. Correlation and regression coefficients of stand with seed weight (Appendix Tables IV and V) indicate that stand does not influence the weight of seed of either of the species significantly. The weight of seed is influenced by the number of seed per pod. Correlation coefficients between number of seed per pod and seed weight provides a low but significant negative correlation for oriental yellow mustard but no relationship of these two variables for yellow mustard.

Correlation coefficients for all three tests with both species were negative. The two significant correlations were obtained for oriental yellow mustard in the five-pound per acre rate of seeding trial planted with various seed sizes and the rate of seeding trial. It will be remembered that these are the two instances where there was a relationship of stand to pods on the central raceme. Stands in these two tests exceeded 110 plants per sixteen square feet.

Previous investigations indicate that two factors, stand and number of pods per plant, are more readily influenced by environmental factors than the other two yield components. Number of seed per pod and weight of seed are not as readily influenced by seeding rate, seed size planted, or other variables.

G. Prediction of yield from four components: Several workers have tried to evaluate formulas expressing the relationship of yield components in barley and oats (7). Means of the different components such as number of plants, number of tillers, length of panicle, number of panicle and weight of panicle have been used. An attempt was made to use the four components of yield in mustard, namely number of plants per unit area, number of pods, number of seed per pod, and seed weight in grams, for predicting the yield of mustard. From the data obtained for the three experiments conducted at Bozeman, correlation and regression coefficients were determined for the relationship of these four components to yield. These are reported in Table XXXV.

Studies were made regarding the influence of each component on each other and the information is recorded in Tables XXXIII and XXXIV.

Examination of the data of Table XXXV reveals that in oriental yellow mustard, a significant positive correlation of stand and seed weight to yield exists, indicating that these two factors influenced yield of oriental yellow mustard. The other two components also influence yield but they did not exert a significant influence in these tests.

In yellow mustard, we find a significant positive correlation between stand and yield. Non-significant influences of other factors on yield were obtained.

Table XXXV. Correlation and regression coefficients of yield component measurements (X) and yield (Y) in pounds per acre.

Variables Correlated	Relation of Yield Component Measurements and Yield in Pounds Per acre					
	Oriental Yellow Mustard			Yellow Mustard		
	r	b_{yx}	$\bar{Y}-b_{yx}(\bar{x})$	r	b_{yx}	$\bar{Y}-b_{yx}(\bar{x})$
Number of pods and yield	0.176	10.599	1500.90	0.061	2.614	1530.00
Number of seed per pod and yield	0.036	5.892	1838.30	0.098	19.500	1561.60
Seed weight and yield	0.312**	3243.000	738.80	0.138	892.800	1041.70
Stand and yield	0.419**	3.500	951.00	0.530**	6.400	605.70

*Significant at 5 per cent level.

**Significant at 1 per cent level.

It may be reiterated that the individual components influence each other, as discussed earlier, and thus have a combined influence on yield. Partial and/or multiple correlation and regression coefficients values should be calculated before a total influence of any one factor on yield could be predicted with accuracy.

Actually, only an approximate 28 per cent of the within test variations in yield for both types of mustard is accounted for by the determinations of components as made in these tests. It should be remembered that only the pods on the terminal raceme were counted and not the total pods on each plant. These tests also represented a range in stands that were associated both positively and negatively with yield.

If the objective is to predict yields of commercial fields of mustard, the most accurate prediction formulas would be based on data collected from these fields. A limitation of this data is readily evident as within test variations permit little variation of seed weight in contrast to what would occur on a field-to-field basis.

Trials such as reported here are probably typical, but indicate some of the problems that may be encountered in developing a satisfactory prediction formula.

DISCUSSION

From the very beginning, we find that size of seed influences emergence, especially as the depth of seeding is increased. Using smaller sized seed, depth of seeding should not be more than two inches. The effect of seed size on stand can be balanced by increasing the seeding rate. Usually the per cent emergence from smaller sized seed is less in comparison to larger seed of the same species. To obtain a uniform stand, a higher seeding rate of the smaller sized seed may be used. If equal numbers of seed are planted, the largest size will give the best germination and emergence.

We further find, that in oriental yellow mustard, a seeding rate of 5.2 pounds per acre of the largest seed or 5 pounds per acre of the next smallest seed gave the highest yield at Bozeman. The number of plants per 16 square feet obtained was 104 and 103, respectively. In the rate of seeding trial with oriental yellow mustard, significant variation in stand is noted, but yield is not appreciably affected beyond a stand of 110 plants per 16 square feet. The seed size index also seems to be influenced by seed size. If we study seed size index in relation to stand we can see that beyond a certain point the seed size decreases as the stand increases in oriental yellow mustard. Test weight follows a different pattern than seed size in oriental yellow mustard. With increasing stand the test weight also increases irrespective of seed size planted differences. The smaller seed size may have the highest test weight if the number of plants per unit area is more. Further examination of the number of pods on the terminal raceme reveals that till a stand of about 110 plants per sixteen square feet is reached, the number of pods increases and beyond this limit, as the number of plants increase, the number of pods on the terminal raceme decreases in oriental yellow mustard. A similar trend is noted relative to the stand and number of seed per pod, though the differences are not significant.

As mentioned earlier, the yield beyond a stand of 110 plant per 16 square feet, did not change materially in the rate of seeding trial and the highest yield was obtained with a stand of 103 to 104 plants per sixteen square feet in the seed size trial. We have discussed the relation of stand to other yield components. We may note that increasing seeding rates or stands beyond a certain limit results in decrease of the number of pods per unit area, and the number of seed per unit area. An increase in stand may also decrease the amount of branching which was not studied. All these effects together may be associated with the decrease in yield of oriental yellow mustard when the stands are greater than 100 to 110 plants per sixteen square feet.

From the preceeding discussion, it can be inferred that the largest seed size of oriental yellow mustard if seeded at the rate of 5.2 pounds per acre would produce the highest yield with greatest seed size index and highest test weight.

If a composite mixture of all sizes of seed is to be used, the seeding rate of five pounds per acre for irrigated land and ten pound or more for dryland may be desirable for the best results with oriental yellow.

In yellow mustard, we find a significant positive correlation between stand and yield. In the seed size experiment, we find that as we continue to increase the number of seed of the smaller size we obtain higher yields. The same trend is found in the seeding rate trial until a rate of about eight pounds is reached when the yield starts decreasing, though the variation in yield is not significant. On dryland, the yield appears to go higher as the seeding rate is increased to 10 pounds.

In yellow mustard, when equal numbers of seed of all seed sizes planted categories are planted, the larger seed produces seed with a higher seed size index. When seed is planted at a constant weight, the results are reversed irrespective of stand. When we consider test weight we find a significant positive correlation between stand and test weight, though distribution due to seed size planted or seeding rate appears to be at random. It is unfortunate that higher plant population, beyond 110 plants per 16 square feet, were not obtained for yellow mustard. Perhaps the definite effects of thicker stands as evident in oriental yellow mustard were not operative.

The highest yield, the highest seed size index, and highest test weight were obtained by planting the largest seed size of yellow mustard at the rate of 9.7 pounds per acre.

SUMMARY

A seed size trial planted with equal numbers of seed per unit area and a rate of seeding trial was conducted at three Montana locations, Bozeman, Havre, and Sunburst. A seed size trial planted with equal weight of seed was conducted at Bozeman only. A test for emergence for different depths was conducted with different sized seed in the greenhouse. Two species of mustard, oriental yellow, and Brassica juncea, and yellow, Brassica hirta, were used for this study.

These four tests were designed to estimate the influence of seed size, seeding depth, and seeding rate on yield and seed quality of mustard. The effect of location on yield and seed quality was also determined.

Germination of the various sizes of seed used revealed no apparent influence of seed size on germination in either species. There was some variation in per cent germination of two seed sizes in oriental yellow but it appeared to be due to reasons other than seed size per se.

Emergence of the different seed sizes of the two mustard species from different depths in the greenhouse revealed significant influences of sizes and depths of planting on emergence in both the species. Field stand at Bozeman and Havre showed an influence of size of seed planted on field stand. Differences in stand due to location were apparent. These differences were not the same for both species.

Seeding rate influenced stands of both species significantly and this influence was not the same for both species. Changes in the effects of seeding rates due to locations were observed.

The effect of seed size or seeding rate in relation to yield and seed quality revealed that the largest seed size of both species, planted on irrigated land, produced the highest yields when seeded at rates of 5. to 5,2 pounds per acre and 9.7 pounds per acre for oriental yellow mustard and yellow mustard, respectively. These seeding rates produced an optimum stand of 110 plants per 16 square feet for oriental yellow mustard. It was not established whether the maximum 105 plants per 16 square feet established with yellow mustard was the optimum number of plants for this species. The seed thus produced had the highest seed size index and test weight.

It was observed that the stand influenced yield components such as number of pods per terminal raceme and number of seed per pod. These in turn influenced seed weight, stand also influenced seed size index and test weight.

Observations revealed that an increase of stand of oriental yellow mustard beyond 100-110 plants per sixteen square feet resulted in decreases of average number of pods per terminal raceme, number of seed per pod, yield, seed size index, and test weight. At stands below this optimu quality measurements and yield components showed a tendency to decrease.

It could be concluded that the seeding rate of oriental yellow mustard should be such as to provide an optimum stand of 100 to 110 plants per 16 square feet as determined in the trials. It may be concluded that a seeding rate of five pounds per acre on irrigated land and ten pounds per acre on dry land may be used for oriental yellow mustard. It would be well to establish rates on the basis of number of plants per unit area, however, definite recommendations for yellow mustard cannot be made as stands beyond the apparent optimum were not obtained. The seed size trial indicated that a seeding rate of 9-10 pounds per acre on irrigated land and ten pounds or more on dry land may produce the best results.

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APPENDIX

Appendix Table I. Correlation and regrassion coefficients for stand (X) and number of pods per terminal raceme (y) for experiments conducted at Bozeman.

Type of Experiment	Relation Between Stand (No. of Plants Per 16 Square Feet) and Number of Pods Per Terminal Raceme					
	Oriental Yellow			Yellow Mustard		
	r	byx	$\bar{Y}$-byx ($\bar{x}$)	r	byx	$\bar{Y}$-byx($\bar{x}$)
1. Seed size experiment planted with constant number of seed per unit area.1/	-0.061	-0.021	40.00	-0.159	-0.0879	59.86
2. Seed size experiment planted with a constant weight of seed per unit area.1/	-0.657**	-0.180	64.00	-0.158	-0.040	58.27
3. Rate of seeding trial	-0.659**	-0.061	48.85	+0.053	-0.011	56.56
All experiments combined	-0.532**	-0.066	47.55	-0.047	-0.016	55.71

1/ Coefficients freed of seed seed size effect.

* Significant at 5 per cent level.
** Significant at 1 per cent level.

Appendix Table II. Correlation and regression coefficients for stand (X) and number of seed per pod (y). for experiments conducted at Bozeman.

Type of Experiment	Relations Between Stand (No. of Plants Per 16 Square Feet) and Number of Seed Per Pod					
	Oriental Yellow			Yellow Mustard		
	r	byx	$\bar{Y}$-byx ($\bar{x}$)	r	byx	$\bar{Y}$-byx ($\bar{x}$)
1. Seed size experiment planted with constant number of seed per unit area.1/	0.465	0.086	3.150	0.141	0.069	-0.59
2. Seed size experiment planted with constant weight of seed per unit area.1/	0.189	0.020	12.337	-0.307	-0.011	6.64
3. Rate of seeding trial	-0.117	-0.001	16.530	0.201	0.004	5.54
All experiments combined	-0.013	-0.0003	15.433	0.0439	0.0003	5.63

1/ Coefficients freed of seed size effect.

* Significant at 5 per cent level.
** Significant at 1 per cent level.

Appendix. Correlation and regression coefficients for number of pods per terminal raceme
Table III. (X) and number of seed per pod (y) for experiments conducted at Bozeman.

Type of Experiment	Relations Between Number of Pods Per Terminal Raceme and Number of Seed Per Pod					
	Oriental Yellow Mustard			Yellow Mustard		
	r	byx	$\bar{Y}$-byx ($\bar{x}$)	r	byx	$\bar{Y}$-byx ($\bar{x}$)
1. Seed size experiment planted with constant number of seed per unit area.1/	-0.270	-0.101	18.48	-0.230	-0.036	7.44
2. Seed size experiment planted with a constant weight of seed per unit area.1/	0.104	0.055	11.29	0.009	0.002	5.74
3. Rate of seeding trial	0.074	0.017	15.66	0.075	0.006	4.44
Three experiments combined	-0.005	-0.002	15.47	-0.006	-0.001	5.73

1/ Coefficients freed of seed size effect.

* Significant at 5 per cent level.
** Significant at 1 per cent level.

Appendix Table IV. Correlation and regression coefficients for stand (X) and seed weight in grams (y) for experiments conducted at Bozeman

Type of Experiment	Relation Between Stand and Seed Weight in Grams					
	Oriental Yellow Mustard			Yellow Mustard		
	r	byx	$\bar{Y}$-byx ($\bar{x}$)	r	byx	$\bar{Y}$-byx ($\bar{x}$)
1. Seed size experiment planted with constant number of seed per unit area.1/	0.008	0.00002	0.339	0.056	0.0005	0.625
2. Seed size experiment planted with a constant weight of seed per unit area.1/	-0.256	-0.00060	0.459	0.287	0.0009	0.442
3. Rate of seeding trial	0.136	0.00002	0.369	-0.130	-0.0002	0.736
All experiments combined	0.047	0.00002	0.348	-0.038	-0.0001	0.777

1/ Coefficients freed of seed size effect.

* Significant at 5 per cent level.
** Significant at 1 per cent level.

Appendix Table V. Correlation and regression coefficients for number of pods per terminal raceme (X) and seed weight in grams (y) for experiments conducted at Bozeman.

Type of Experiment	Relation Between Number of Pods Per Terminal Raceme and Seed Weight in Grams					
	Oriental Yellow Mustard			Yellow Mustard		
	r	byx	$\bar{Y}$-byx ($\bar{x}$)	r	byx	$\bar{Y}$-byx ($\bar{x}$)
1. Seed size experiment planted with constant number of seed per unit area.1/	0.243	0.002	0.262	0.224	0.003	0.520
2. Seed size experiment planted with a constant weight of seed per unit area.1/	0.396	0.002	0.299	0.063	0.003	0.709
3. Rate of seeding trial	-0.054	-0.002	0.381	-0.005	-0.00004	0.718
Three experiments combined	0.156	0.001	0.330	0.048	0.0003	0.689

1/ Coefficients freed of seed size effect.

* Significant at 5 per cent level.
** Significant at 1 per cent level.

Appendix Table VI. Correlation and regression coefficient for number of seeds per pod (X) and seed weight in grams (y) for experiments conducted at Bozeman.

Type of Experiment	Relation Between Number of Seed Per Pod and Seed Weight in Grams					
	Oriental Yellow Mustard			Yellow Mustard		
	r	byx	Y-byx ($\bar{x}$)	r	byx	Y-byx ($\bar{x}$)
1. Seed size experiment planted with a constant number of seed per unit area.1/	-0.330	-0.007	0.450	-0.136	-0.011	0.734
2. Seed size experiment planted with a constant weight of seed per unit.1/	-0.515*	-0.005	0.458	-0.091	-0.002	0.734
3. Rate of seeding trial	-0.449**	-0.002	0.412	-0.260	-0.030	0.891
Three experiments combined	-0.328**	-0.005	0.447	-0.047	-0.005	0.732

1/ Coefficients freed of seed size effect.

* Significant at 5 per cent level.
** Significant at 1 per cent level.

Appendix Table VII. Correlation and regression coefficients for number of pods per terminal raceme (X) and yield in pounds per acre (y) for experiments conducted at Bozeman.

Type of Experiment	Relation Between Number of Pods Per Terminal Raceme and Yield in Pounds Per Acre					
	Oriental Yellow Mustard			Yellow Mustard		
	r	byx	$\bar{Y}$-byx ($\bar{x}$)	r	byx	$\bar{Y}$-byx ($\bar{x}$)
1. Seed size experiment with a constant number of seed per unit area planted.1/	0.675**	57.672	-674.70	-0.086	-8.434	2102.00
2. Seed size experiment planted with a constant weight of seed per unit.1/	0.393	21.780	1090.30	-0.067	-1.224	1918.90
3. Rate of seeding trial	-0.345*	-16.269	2789.20	0.203	11.990	898.00
Three experiments combined	0.176	10.599	1500.90	0.061	2.614	1530.0

1/ Coefficients freed of seed size effect.

* Significant at 5 per cent level.
** Significant at 1 per cent level.

Appendix Table VIII. Correlation and regression coefficients for number of seeds per pod (X) and yield in pounds per acre (y) for experiments conducted at Bozeman.

Type of Experiment	Relation Between Number of Seed per Pod and Yield in Pounds Per Acre					
	Oriental Yellow Mustard			Yellow Mustard		
	r	byx	$\bar{Y}$-byx ($\bar{x}$)	r	byx	$\bar{Y}$-byx ($\bar{x}$)
1. Seed size experiment planted with constant number of seed per unit area.1/	0.010	2.216	1555.4	0.428	274.560	128.50
2. Seed size experiment planted with a constant weight of seed per unit area.1/	0.091	9.618	1828.5	0.009	0.623	1848.50
3. Rate of seeding trial.	0.009	1.980	2074.5	0.330*	224.76	263.40
Three experiments combined	0.036	5.892	1838.3	0.098	19.50	1561.60

1/ Coefficients freed of seed size effect.

* Significant at 5 per cent level.
** Significant at 1 per cent level.

Appendix Table XIX. Correlation and regression coefficients for seed weight in grams (X) and yield in pounds per acre (y) for experiments conducted at Bozeman.

Type of Experiment	Relation Between Seed Weight in Grams and Yield in Pounds Per Acre.					
	Oriental Yellow Mustard			Yellow Mustard		
	r	byx	$\bar{Y}$-byx ($\bar{x}$)	r	byx	$\bar{Y}$-byx ($\bar{x}$)
1. Seed size experiment planted with constant number of seed per unit area.1/	0.301	2946.96	580.2	0.292	1629.30	574.4
2. Seed size experiment planted with a constant weight of seed per unit area.1/	0.315	3267.12	713.4	0.050	193.01	1712.3
3. Rate of seeding trial	0.33*	3856.62	675.4	0.107	735.40	1040.5
Three experiments combined	0.312**	3243.0	738.8	0.138	892.80	1041.7

1/ Coefficients freed of seed size effect.

* Significant at 5 per cent level.
** Significant at 1 per cent level.