Cultural studies with two species of mustard grown at three locations
by Kailash Prasad Agrawal

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.

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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. <u>Seed size trial with constant seeding rate per acre</u>:- 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. <u>Rate of seeding trial</u>:- 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 $\quad s_{\bar{y}}/\bar{y}$ = 8.5 per cent
$s_{\bar{y}}$ for depths = 2.10 $\quad s_{\bar{y}}/\bar{y}$ = 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		5 pounds per acre
		Bozeman	Havre	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