COMPARISON OF DIFFERENT SEED DIVIDERS USED FOR MIXING AND OBTAINING WORKING SAMPLES

by

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Mixing and Dividing of Seeds

Ahmed

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ABSTRACT

Nine different synthetic mixtures consisting of chaffy and free flowing seeds of various sizes were used to study the efficiency of four dividers (the Kopooshian, the Boerner, the Gamet and the modified halving) in mixing and dividing. The big Kopooshian and the Boerner were used for big chaffy or free flowing seed mixtures. The Gamet and the small Kopooshian were used for small chaffy or free flowing seed mixtures, whereas, the modified halving was used for all kinds of mixtures except those which had *Hordeum vulgare* or *Avena sativa* as the major component.

The small Kopooshian gave better results in mixing and dividing the small free flowing seed mixtures as compared to the Gamet and the modified halving.

With respect to the mixtures of big free flowing seeds, more representative working samples were obtained by the Boerner than the big Kopooshian and the modified halving.

In two of the three mixtures of the small chaffy seeds, the big Kopooshian, the Gamet, and the modified halving gave poor results. The three dividers, however, gave better results with the third mixture, with the small Kopooshian as the best. Representative working samples were obtained by the Boerner than the big Kopooshian with one of the two big chaffy seed mixtures. Both dividers did an extremely poor job with the other mixture.

From the results of this study it was found that more representative working samples were obtained by (a) the small Kopooshian for the small chaffy and free flowing seed mixtures and (b) the Boerner divider for the big

chaffy and free flowing. The big Kopooshian, the Gamet, and the modified halving gave poor and inconsistent results.

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INTRODUCTION

A seed sample received by a laboratory is generally reduced to a small sample of standard weight as prescribed by the International Rules for Seed Testing (2). This small sample for determination of purity, germination, noxious weed seed content, genuiness of variety, and all other determinations is referred to as a "working sample". Because the working sample is essentially small, great care should be taken to ensure that it is truly representative of the bulk sample being analyzed.

The most commonly used method for obtaining the working sample is by mechanical dividers. Two types of dividers are usually available in seed laboratories. One divider is called the "Boerner Divider" and is used for sampling large seeds such as corn, wheat, barley, oats, beans and peas. Another divider is the "Gamet Divider" and is used for small seeds such as alfalfa, clovers and small seeded grasses. At times "modified halving" and "random cups" methods are also used to obtain the working sample.

Impure and mixed seed lots are always more difficult to divide than lots which contain only pure seed. Unequal sample sizes and unrepresentative working samples are problems a seed analyst often encounters when dealing with seed mixtures of varying seed sizes and chaffiness. The improper working of the methods employed to obtain the working sample is supposedly due to poor mixing and dividing.

A comparative and individual study of the different dividers, namely the Boerner, Gamet, and Kopooshian (a new divider developed by Dr. H. Kopooshian at the seed laboratory of the American University of Beirut) as well as the modified halving method, was made with respect to a variety of synthetic free flowing and chaffy seed mixtures.

REVIEW OF LITERATURE

Bulk samples are submitted to seed testing laboratories for tests of purity, germination, noxious weed, genuiness of variety, and other determinations. According to the International Rules for Seed Testing the reduced samples drawn from the bulk are called "working samples" (1). Care is taken to ensure that the working samples represent the material sent for analysis. In a large seed testing station, hundreds of working samples have to be drawn each day. The working samples must be approximately the weight that is prescribed in the International Rules for Seed Testing. It is essential therefore, if the work of the station is to flow smoothly, that the method used should be capable of producing a sample of approximately the desired weight quickly and in a simple fashion.

The International Rules for Seed Testing (1) prescribed the following methods for obtaining the working samples:

(A) Random cups method. Six to eight cups or small containers are placed on a tray at random and the seeds to be divided are scattered over the tray from a pan. The seeds caught in the small containers are used as the working sample, or this may be further reduced if necessary.

(B) Modified halving method. This method is similar to the one mentioned above, but instead of random cups, a modified tray is used. The tray is divided into an even number of square compartments, every alternate one of which has no bottom. When the seeds are shaken over the tray and the tray lifted, half of the sample remains on the pan placed beneath the tray. In this way the sample is repeatedly divided in half until a sample of the desired size is obtained.

(C) Mixing by hand method. The sample is well mixed by hand and spread out in a layer of uniform thickness on a flat tray or mixing basin. Small portions of the seeds are taken with a spoon from different places on the tray, until the proper quantity has been secured.

(D) Mechanical dividers. This method is preferred for free flowing seeds. Certain kinds of chaffy seeds can be successfully mixed and divided by means of an appropriate mechanical divider. After mixing, the sample is repeatedly divided until a portion of approximately the size required for the working sample is obtained.

Thomson and Doyle (13) reported on a comparative study of halving and random cups method for obtaining the working sample. The bulk samples were drawn from a number of species of grasses and clovers namely, _Lolium perenne_, _L. multiflorum_, _Phleum pratense_, _Trifolium pratense_, and also from nine samples of vegetable seeds. From each of the bulk samples, two working samples were drawn by one analyst using the halving method and two other working samples by another analyst using the random cups method. It was found that the halving method tended to give lower values for "weed and crop seeds", and higher values for inert matter, while the reverse was true for the random cups method. The differences between the two methods were due to the nonrepresentative or biased sampling of the impurities. Thus, the "Sampling and Bulking" Committee of the International Seed Testing Association advised the deletion of the halving method and instead recommended the random cups method for drawing the working samples.

According to Thomson (14) the random cup method has the following limitations: "(a) It is based on the assumption that in any one kind of seed there is not a great deal of variation in the size of the bulk sample received. (b) It is not suitable for samples containing coarse material such as straw, unless the straw is first removed from the whole bulk sample and its percentage is calculated".

The mixing by hand method to draw working samples is preferred in many laboratories as it is supposed to save time. The Sampling and Bulking Committee (5) made a study using this method on the following mixtures:

Mixture I. 80 percent Dactylis glomerata, 5 percent each of Phleum pratense, Trifolium repens, T. pratense and Festuca sp.

Mixture II. 80 percent Lolium sp., 5 percent each of Phleum pratense, Trifolium repens, T. pratense and Festuca sp.

Mixture III. 80 percent Phleum pratense, 5 percent each of Trifolium pratense, T. repens and Festuca sp.

Mixture IV. 80 percent Trifolium pratense, 5 percent each of Phleum pratense, T. repens and Festuca sp.

After the separation, the percentages were calculated and all the components were then rebulked. This separation and rebulking was repeated ten times for each sample. The study indicated that the working samples obtained by this method varied consistently for all four mixtures. The mixing by hand method gave too small percentages of small and smooth seeds which were Phleum pratense, Trifolium pratense and T. repens.

Leggat (9) reported the work of Thomson of the Scottish station, who worked with the halving and random cups methods in drawing working samples from duplicate samples of Dactylis glomerata, Lactuca sativa, a mixture of Brassica spp., Phleum pratense, Trifolium pratense, T. repens, Lolium multiflorum and L. perenne. The statistical analysis showed that the halving method was significantly less uniform than was the random cups method.

Apart from the use of the random cups, halving and mixing by hand, a variety of mechanical dividers have been developed namely the Boerner, the Gamet, the Kny-Scheerer, the Hay-Bates, and the Ottawa dividers, to get representative working samples (3).

Carter (4) reported the work of cooperating laboratories and a sampling committee where four synthetic mixtures were used in drawing working samples by the random cups and the halving methods, a "home made" plastic riffle, and the Boerner and the Gamet dividers. The mixtures used were the following:

Mixture I. 90 percent Dactylis glomerata, 2.5 percent each of Phleum pratense, Trifolium pratense, T. repens and Festuca sp.

Mixture II. 90 percent Lolium spp, 2.5 percent each of Phleum pratense, Trifolium pratense, T. repens and Festuca sp.

Mixture III. 90 percent Phleum pratense, 2.5 percent each of Trifolium pratense, T. repens and Festuca sp.

Mixture IV. 90 percent Trifolium pratense, 2.5 percent each of Lolium spp, Phleum pratense, Trifolium repens and Festuca spp.

The results showed that the different mechanical dividers had less variation than did either the halving or the random cups, and that the halving method showed the greatest variation and the random cups intermediate. It is worth noting that the "home made" plastic riffle, which has a static electricity problem in dry climates, is less expensive than is either the Gamet or the Boerner divider. A similar comparative study of the mixing by hand method and the mechanical dividers was also made in the Purdue University laboratory of Indiana (5). The mechanical dividers under study were the Boerner, the Gamet, and the Schall (a divider developed by E.D. Schall for obtaining working samples of feed and fertilizers from the bulk). The latter in the present form, is not well suited to seed sampling because of the tendency of the seed to bounce out in the process of dividing. In general, the three dividers are unbiased in obtaining working samples. However, the three dividers gave different results when repeated working samples were drawn from the same mixture. The Boerner and the Schall dividers gave the least variation, the mixing by hand method was intermediate; and the Gamet divider gave the most variation. Carter (5) believes that there is a need for a new divider which will produce working samples with less variation than will those of the Boerner and the Schall, and that if no mechanical dividers are available, the use of random cups is preferred to other methods.

The Pascall divider (an English manufacture similar to the Gamet divider) and the mixing by hand were compared by Madeson and Olsen (10). On sampling from a mixture of species of different sizes of each and from a mixture of heavy and light seeds Lolium perenne and/or Festuca elatior, too few of the small and heavy seeds were obtained. The variation between samples from the Pascall divider was greater than was that of the mixing by hand method.

It is generally believed that the random cups and the mixing by hand methods of drawing working samples are less accurate than are the mechanical dividers. Justice (8) commented that attempts to divide small samples of five grams or less by the Gamet often resulted in unequal working samples. Isely (7), using the Boerner and the Gamet dividers on the following mixture: Poa pratensis 50 percent, Agrostis sp. 5 percent, Festuca rubra 10 percent and inert matter 10 percent, found that: (a) neither of the dividers work perfectly (b) the Boerner is more efficient than is the Gamet (c) much lack of uniformity in grass seed tests may be attributable to unsatisfactory laboratory sampling.

It was found by Shenberger (12) that the Boerner divider gave representative working samples of a mixture consisting of components with an extreme size ratio of approximately 25 to 1 by weight.

The use of mechanical dividers in drawing working samples is increasing compared to the other methods. However, it is felt that mechanical dividers have certain shortcomings and a new divider that would yield a working sample of the exact size by passing the submitted samples through the divider once is needed (6).

MATERIALS AND METHODS

An experiment was conducted during the years 1963-65 in the Seed Technology laboratory of the American University of Beirut to find the efficacy of several different seed dividers. The Boerner, Gamet, modified halving, and Kopooshian dividers were used in drawing working samples from several different mixtures of seeds. Nine different synthetic mixtures of various grass and crop seeds of varying compositions were prepared as shown in Table 1. Each mixture was composed of four components. These mixtures consisted either of free flowing, or chaffy and free flowing seeds. Depending on the size of the seeds and chaffiness either two or three dividers were used. The Boerner and the big Kopooshian were used for big chaffy and free flowing seed mixtures, whereas, the Gamet was used for small chaffy and free flowing seed mixtures. The modified halving was used for all kinds of seeds except for mixtures 8 and 9 (Table 1), which had the major component bigger than the channel size of this divider.

Preparation of Mixtures

All seeds were sieved and cleaned and only seeds of uniform sizes were used. The average weight of 1000 seeds and the number of seeds per gram of those used in the mixtures are shown in Table 2.

Seeds of Lolium were stained with safranin and of Festuca were stained with methylene blue to facilitate separation. The weight of each component of the mixtures was calculated to the amount recommended by the International Rules for Seed Testing (2). The total weight of each mixture was equal to the eight working samples (subsamples) shown in Table 1.

Table 1. The percentage compositions and weights of the synthetic mixtures of free flowing and chaffy seeds.

	Component	Percentage Composition	Weight (g) Total	Subsample	Dividers Used
Mixture (1)	Trifolium pratense	75	28	3.5	Big Kopoosh-
	Trifolium subterraneum	15	6	0.75	ian, Gamet,
	Lotus corniculatus	10	4	0.50	Modified
	Melilotus indica (Lot A)	5	2	0.25	halving
Mixture (2)	Melilotus indica (Lot A)	50	20	2.50	Small Ko-
					pooshian,
	Trifolium repens	25	10	1.25	Gamet, Mo-
	Medicago orbicularis	15	6	0.75	dified
	Trifolium subterraneum	5	4	0.50	halving
Mixture (3)	Vicia sativa	75	600	75	Big Kopoosh-
	Lens esculentus	15	120	15	ian, Boerner,
	Triticum durum	5	40	5	Modified
	Melilotus indica (Lot A)	5	40	5	halving
Mixture (4)	Triticum durum	75	600	75	Big Kopoosh-
	Hordeum vulgare	10	80	10	ian, Boerner,
	Sorghum vulgare	10	80	10	Modified
	Trifolium subterraneum	5	40	5	halving

Table 1 continued

	Component	Percentage Composition	Weight (g) Total	Weight (g) Subsample	Dividers Used
Mixture (5)	*Agropyron elongatum*	70	42	5.25	Big Kopoosh-
	Festuca arundinacea (blue)	5	3	0.375	ian[a], Gamet, Modified
	Gynodon dactylon	5	3	0.375	halving
	Lolium multiflorum	20	12	1.50	
Mixture (6)	*Bromus inermis*	70	28	3.5	Big Kopoosh-
	Lolium multiflorum (red)	20	8	1.0	ian, Gamet,
	Phalaris tuberosa	5	2	0.25	Modified halving
	Gynodon dactylon	5	2	0.25	
Mixture (7)	*Lolium multiflorum* (red)	50	20	2.5	Small Ko-
	Festuca arundinacea (blue)	40	16	2.0	pooshian, Gamet,
	Melilotus indica (Lot B)	5	2	0.25	Modified
	Lotus corniculatus	5	2	0.25	halving
Mixture (8)[b]	*Hordeum vulgare*	75	600	75	Big Kopoosh-
	Triticum durum	10	80	10	ian, Boerner
	Sorghum vulgare	10	80	10	
	Melilotus alba	5	40	5	

Table 1 continued

	Component	Percentage Composition	Weight (g) Total	Subsample	Dividers Used
Mixture (9)	Avena sativa	75	600	75	Big Ko-
	Triticum durum	10	80	10	pooshian,
	Hordeum vulgare	10	80	10	Boerner
	Molilotus indica (Lot B)[c]	5	40	5	

[a] The big and small Kopooshian indicate the divider of 1.5 cm. and 1 cm. channel size respectively.

[b] The modified halving was not used for the mixtures (8) and (9) because the seed size of the major component was bigger than the size of the individual compartments of the divider.

[c] Lot A and Lot B indicate the seed of different sizes obtained after sieving.

Table 2. The average weight of the 1000 seeds and number of seeds per gram.

Component	Average weight of 1000 seeds (g)	Number of seeds per gram
Agropyron elongatum	6.2766	159
Avena sativa	28.8892	35
Bromus inermis	1.4831	674
Cynodon dactylon	0.3031	3300
Festuca arundinacea (blue)	2.6548	377
Hordeum vulgare	47.8281	20
Lens esculentus	59.3337	17
Lolium multiflorum (red)	2.6863	403
Lotus corniculatus	1.1688	830
Melilotus alba	1.9909	502
Melilotus indica Lot A	2.1441	474
Lot B	1.7531	571
Medicago orbicularis	2.5235	396
Phalaris tuberosa	1.4778	691
Trifolium pratense	2.0448	888
T. repens	0.6688	1495
T. subterraneum	6.4736	143

Methods of Sampling and Dividing

Each component of the mixtures was weighed to two decimal places, put together and then passed three times through the divider to ensure complete mixing.

A definite pattern of subdividing the mixtures was used for all the dividers studied. This pattern which is illustrated in figure 1 shows clearly the position of each working sample with respect to the left and right spout of the dividers. The eight working samples obtained after the division were kept separately and weighed up to four decimal places. Each of the working samples was separated by hand, with the help of sieves, into their different components which were weighed to four decimal places.

Description and Operation of the Dividers

Four different dividers were used in this study, namely the Boerner, Gamet, modified halving and Kopooshian.

(a) Boerner: This is the most commonly used mechanical divider for big seeds, figure 2. The essential parts are a hopper, two receiving pans, an inverted cone and a set of thirty six alternate channels that direct the seeds into two separate spouts. The seeds are retained by means of a valve or a gate at the base of the hopper. When the valve is opened, the seed in the hopper passes down by gravity through the alternate channels and the whole seed mixture is then separated into two equal subsamples.

(b) Gamet: This divider is meant for small seeds. The essential parts consist of a hopper, shaft, electric motor and two receiving pans. The seeds are poured in the hopper and the electric motor

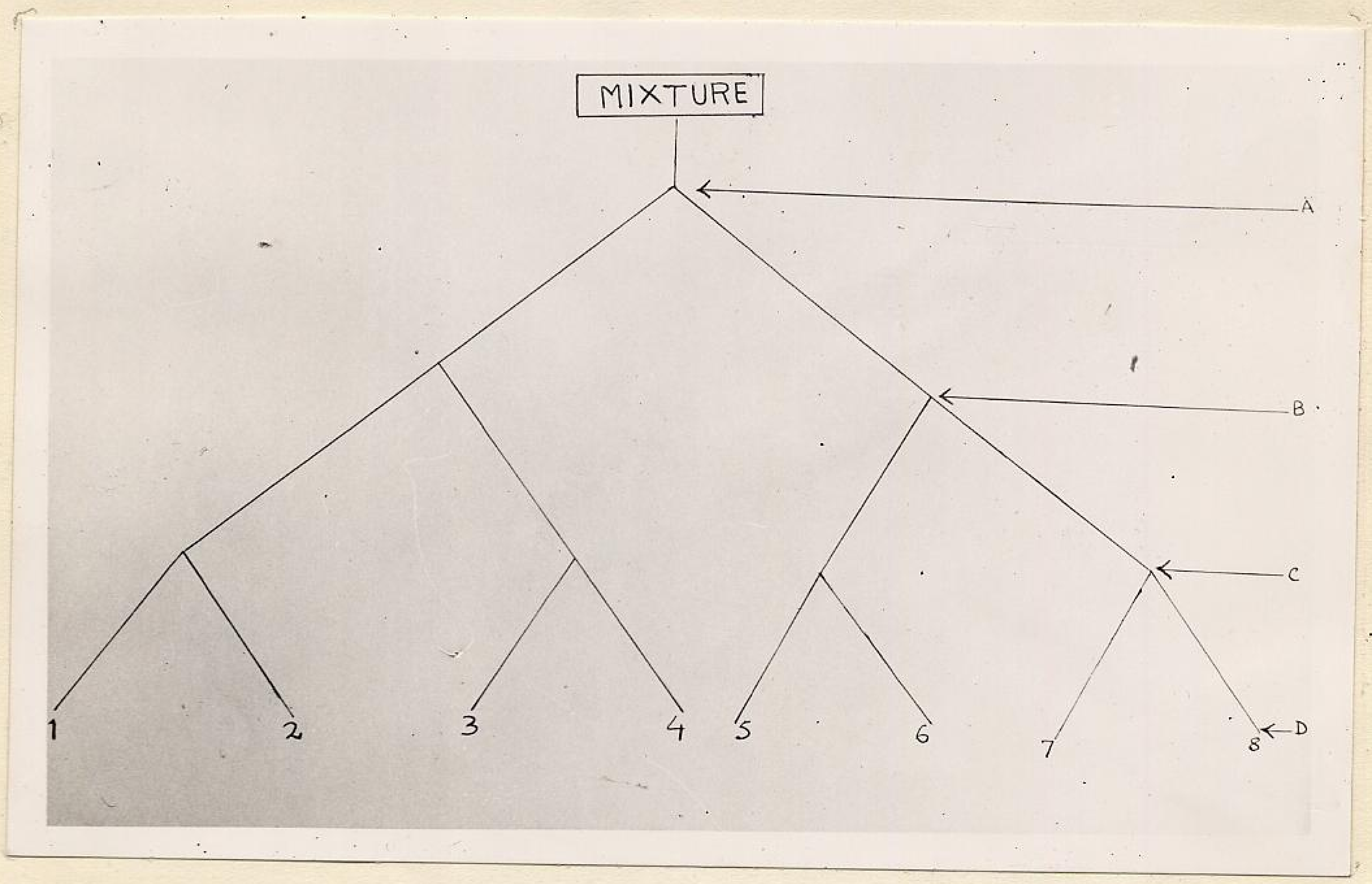

Figure 1. Flow diagram to show derivation of subsamples

1 - 4 = Subsamples of left spout.

5 - 8 = Subsamples of right spout.

A = First division.

B = Second division.

C = Third division.

D = Final division.

Figure 2. The Boerner divider.

rotates the shaft which helps to throw the seeds into two receiving pans thus dividing the sample into two halves (figure 3).

(c) Modified halving: The essential parts are a tray and a pan. The tray has hundred (10 x 10) square compartments. Every alternate compartment has no bottom. Each compartment is 1.5 x 1.5 cm. square. The seeds are shaken over the tray and then the tray is lifted leaving half the seeds remaining in the tray and half in the pan (figure 4).

(d) Kopooshian divider: Figure 5 illustrates the assembled divider. It is composed of (i) two body types, big and small, which contain the channels; (ii) a hopper with a butterfly gate; (iii) two receiving pans. The small type has 20 alternate channels each one cm. wide and the big has 14 channels each of 1.5 cm. wide. The channels are arranged so that alternate ones lead to each of two receiving pans. Depending on the size or chaffiness of the seed mixtures, either big or small Kopooshian is used.

After pouring the seeds in the hopper, the gate is opened slowly by means of a handle allowing the seeds to pass through the alternate channels to be caught in the two receiving pans.

The chi-square test (11) of the goodness of fit was employed to detect the homogeneity of the working samples obtained by these dividers. Since only numbers can be analyzed by chi-square, the weights were multiplied by their respective number of seeds per gram to change it to number.

Figure 3. The Gamet divider.

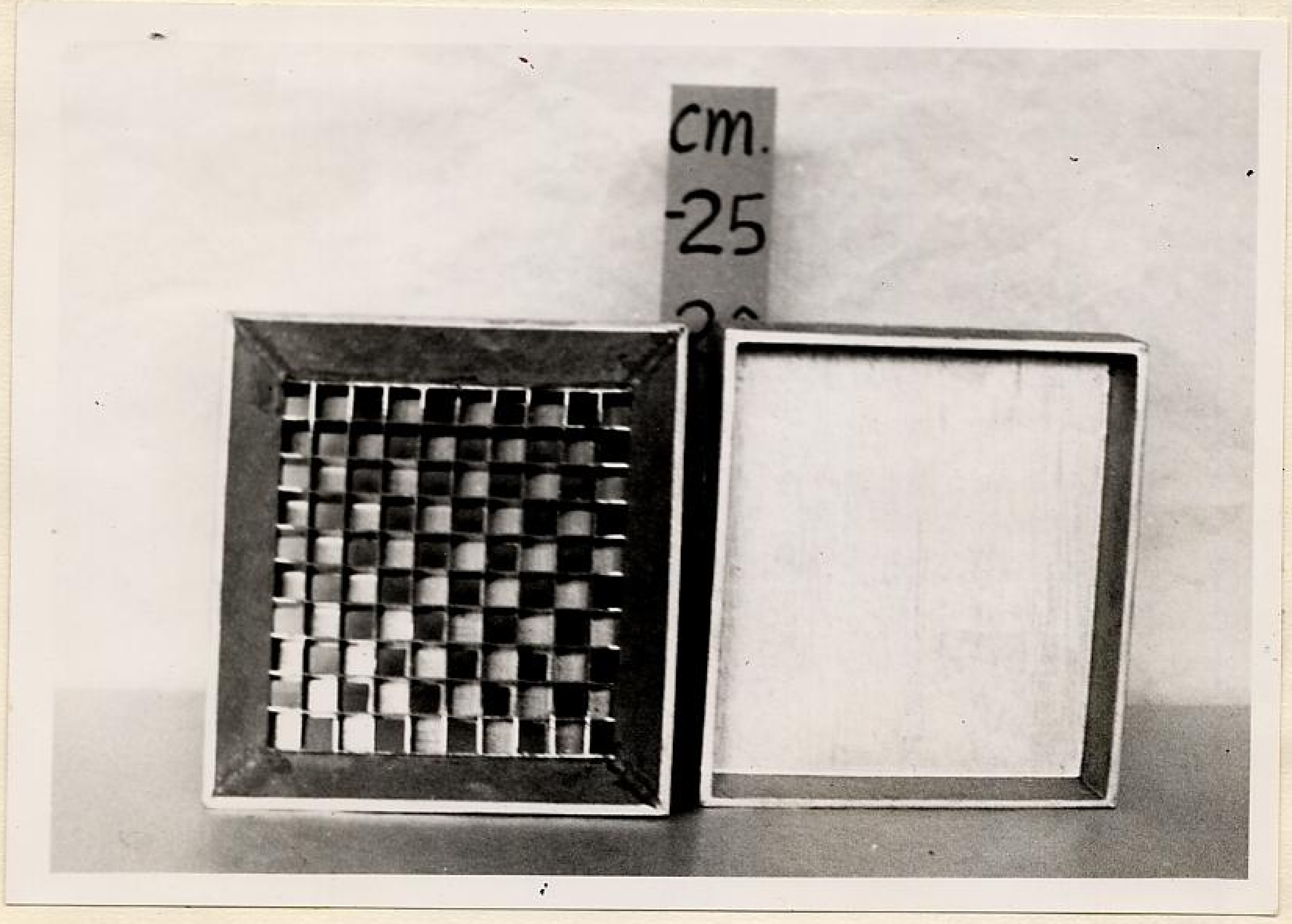

Figure 4. The modified halving.

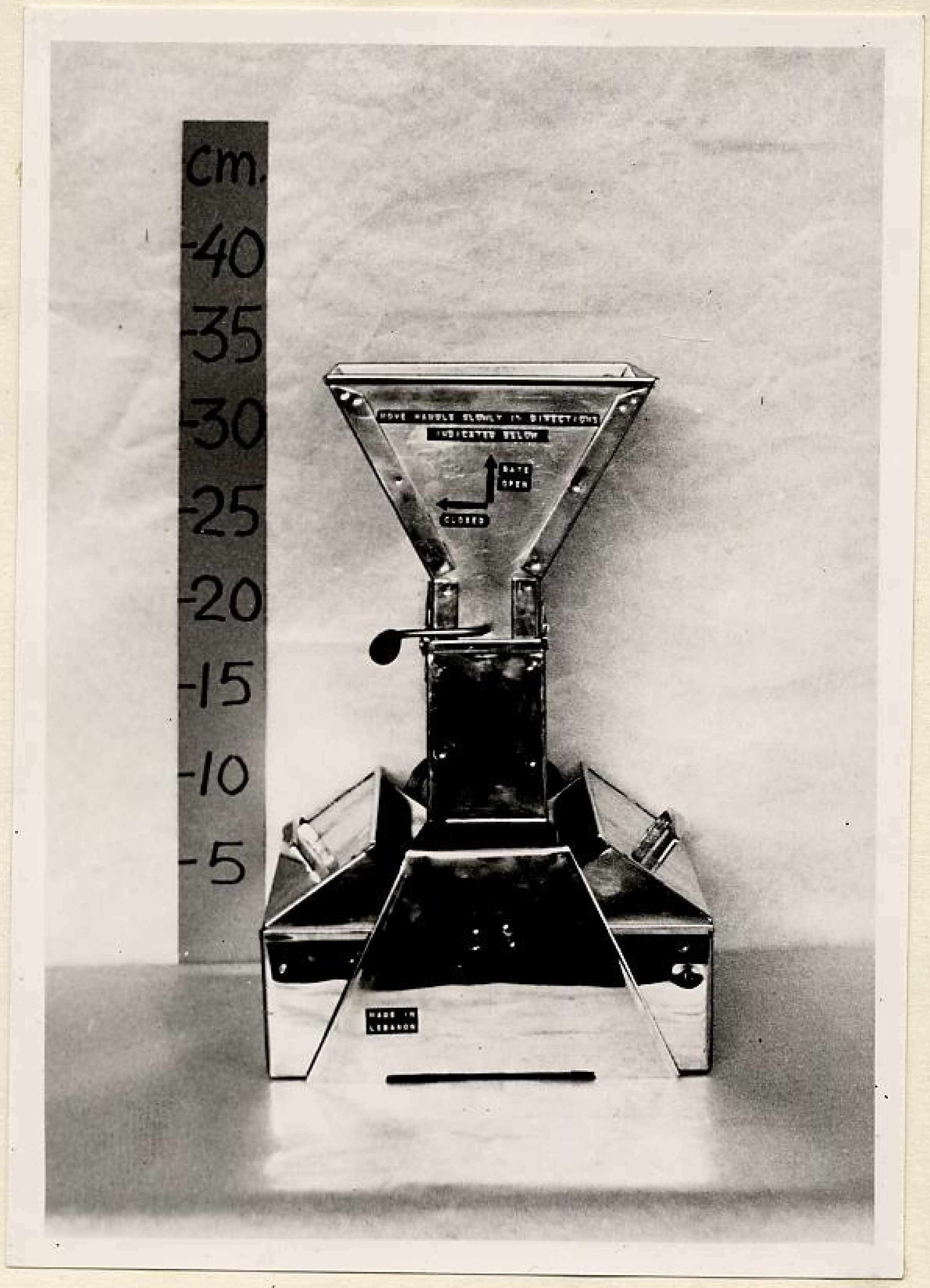

Figure 5. The Kopooshian divider.

RESULTS AND DISCUSSION

Four types of dividers namely, the Kopooshian, the Boerner, the Gamet, and the modified halving method were studied with respect to nine different types of seed mixtures. The chi-square test was employed to study the efficiency of these dividers in mixing, dividing and obtaining working samples. The chi-square values of the individual components of each working sample of all the mixtures are shown in tables 3 to 11. In addition, the weights of the individual components of the working samples of all the mixtures are shown in the appendix.

Mixtures of Small Free Flowing Seeds

The small Kopooshian, the Gamet, and the modified halving method were used in drawing the working samples from the two synthetic mixtures of small free flowing seeds.

It can be seen from the data in table 3 that the small Kopooshian gave better results than did either the Gamet or the modified halving method, and that the Gamet was better than the modified halving. In case of the small Kopooshian, only the working sample number four is non-homogenous, as it showed to be significant, whereas, in case of the Gamet, the working samples number one, two, three, six, seven and eight are significant. The working samples number one, four, five, six and eight obtained by the modified halving are highly significant. These results are in agreement with Carter (4) where it was found that mechanical dividers gave less variation than did the halving method.

The size of the working samples drawn by the small Kopooshian

Table 3. Subsample weight, individual chi-square of the different components, and total chi-square values of mixture 1 for different dividers.

Divider	Subsample Number	Subsample Weight (g)	Individual chi-square values A	B	C	D	Total chi-square values
Small Kopooshian	1	5.2833	0.0037	0.1672	0.0778	2.3906	2.6393
	2	4.9001	1.3775	0.3622	0.3952	0.7081	2.8430
	3	5.1788	0.0289	0.2154	0.2268	0.4685	0.9396
	4	4.9874	1.4849	0.4642	3.4468	3.1453	8.5412^{+}
	5	5.1771	0.0252	0.9421	1.7001	2.6720	5.3394
	6	4.9774	0.0573	0.2994	0.5437	0.0326	0.9330
	7	4.9987	0.3736	0.7436	1.0142	0.1743	2.3057
	8	4.9286	3.7884	2.1863	0.4659	0.0436	6.4842
Gamet	1	5.8963	9.7358	4.3523	2.2913	0.0574	16.4368^{++}
	2	5.2195	8.8899	13.8541	6.4818	0.3123	29.5381^{++}
	3	5.0105	6.0401	9.0950	2.8097	0.9467	18.8915^{++}
	4	4.6091	0.8775	0.6805	0.0458	0.2576	1.8614
	5	4.6184	0.2915	1.4545	1.8279	0.9086	4.4825
	6	4.4091	4.3597	4.0673	0.0111	0.6458	9.0839^{+}
	7	5.2264	2.8765	8.9521	8.4685	3.3337	23.6308^{++}
	8	5.3161	2.6881	3.6835	0.1778	2.4859	9.0354^{+}
Modified halving	1	5.6836	8.5054	16.9127	9.9808	2.2595	37.6584^{++}
	2	5.0764	0.7771	2.3563	3.3548	0.0166	6.5048
	3	4.5046	0.0177	0.0009	0.0369	0.0079	0.0634
	4	4.8951	10.1079	14.3347	5.1579	0.3149	29.9144^{++}
	5	5.1806	5.3461	6.2827	0.3118	1.6798	13.6204^{++}
	6	5.0201	12.1753	10.6462	0.4433	0.0971	23.3619^{++}
	7	4.9991	0.4683	0.3561	0.0980	0.3607	1.2831
	8	4.4151	29.1585	49.3421	19.0858	8.4683	106.0547^{++}

Mixture 1: A = *Melilotus indica* 50% (20.0 g)

B = *Trifolium repens* 25% (10.0 g)

C = *Medicago orbicularis* 15% (6.0 g)

D = *Trifolium subterraneum* 10% (4.0 g)

Subsample weight A + B + C + D = 5.0 g.

$^{+}$ Significant at 5% level

$^{++}$ Significant at 1% level

ranged from 4.9001 to 5.2833 g. From the Gamet, the range was 4.4091 to 5.8963 g. and 4.4151 to 5.6836 g. in the modified halving. The working sample weights obtained by the small Kopooshian were closer to the expected weight (5.0 g.) than were either the Gamet or the modified halving.

The study of mixture 2 (table 4) of small free flowing seeds indicated that the small Kopooshian gave better results than did the Gamet or the modified halving because all the chi-square values of the small Kopooshian samples were non-significant. In the case of the modified halving, one or more of the components namely, *Trifolium pratense*, *T. subterraneum*, *Lotus corniculatus* and *Melilotus indica* contributed high chi-square values. These high chi-square values were probably a result of either improper mixing or dividing of the seeds. With respect to the Gamet, only the working sample number six was significant (1% level).

The weights of the working samples in the small Kopooshian and the modified halving ranged from 4.4035 to 5.3231 g. and 4.7131 to 5.4521 g., respectively, which are relatively close to the expected amount of 5.0 g. compared to the wide range of the weights from the Gamet which was 4.0646 to 6.0531 g.

The small Kopooshian gave better results than did the Gamet or modified halving. In mixture 1 (table 3) the Gamet and the modified halving gave approximately the same results but in mixture 2 (table 4) the Gamet was better than the modified halving.

Mixtures of Big Free Flowing Seeds

The data from the test using two mixtures of big free flowing

Table 4. Subsample weight, individual chi-square of the different components, and total chi-square values of mixture 2, for different dividers.

Divider	Subsample Number	Subsample Weight (g)	Individual chi-square values A	B	C	D	Total chi-square values
Small Kopooshian	1	4.4035	0.3046	0.9174	0.0057	0.6894	1.9171
	2	5.1354	0.0009	0.9100	0.9997	0.8668	2.7774
	3	5.0611	0.0006	0.0040	0.0357	5.0131	5.0534
	4	5.1051	0.0043	0.5634	2.1153	0.0208	2.7038
	5	4.8796	0.1858	0.0178	2.4891	0.5983	3.2910
	6	5.2275	0.8758	0.0010	0.0000	1.5916	2.4676
	7	5.3231	0.0080	0.7292	0.5725	0.1641	1.4738
	8	4.7537	0.0093	0.7297	1.7847	0.0005	2.5242
Gamet	1	5.1105	0.7808	1.2306	0.0253	0.0025	2.0392
	2	4.0646	0.0443	1.8825	0.0020	5.6064	7.5352
	3	5.1551	1.1603	1.1967	0.9562	1.3114	4.6246
	4	4.6628	0.3592	0.9977	0.3550	0.1134	1.8253
	5	5.2804	0.2346	0.0703	0.3790	1.1815	1.8654
	6	5.1325	4.0250	1.4488	0.5794	7.1841	13.2373++
	7	6.0531	0.3135	0.0767	0.0153	0.2330	0.6385
	8	4.3197	0.1656	0.2740	0.3712	1.2014	2.0122
Modified halving	1	4.8619	1.4789	6.6276	0.0026	0.0138	8.1229+
	2	4.7058	0.0294	8.0206	4.3974	0.0003	12.4477++
	3	4.8977	0.6369	0.3685	0.2129	0.2345	1.4524
	4	4.7131	0.0005	1.1130	0.1055	0.0639	1.2829
	5	4.9233	0.1382	1.0012	0.1458	4.7302	6.0154
	6	4.9911	0.2660	0.2835	2.2090	2.6078	5.3663
	7	5.4521	0.0474	6.3981	1.5825	1.5435	9.5715+
	8	5.2355	0.5589	5.2912	3.8295	1.0428	10.7224+

Mixture 2: A = Trifolium pratense 70% (28.0 g)

B = T. subterraneum 15% (6.0 g)

C = Lotus corniculatus 10% (4.0 g)

D = Melilotus indica 5% (2.0 g)

Subsample weight A + B + C + D = 5.0 g.

+ Significant at 5% level
++ Significant at 1% level

seed are shown in tables 5 and 6. Three dividers namely the big Kopooshian, the Boerner and the modified halving were used in obtaining working samples from these mixtures.

The data of mixture 3 (table 5) indicated that the Boerner gave better results than did the big Kopooshian or the modified halving. The six working samples obtained by the Boerner were non-significant, whereas, in the case of the big Kopooshian, only two were non-significant and in the modified halving five chi-square values were non-significant. There was much variation between the weights of the working samples obtained from the modified halving. These weights ranged from 80.5474 to 126.6500 g. The range of the working sample weights was low in the case of the big Kopooshian (93.8066 to 107.0664 g.) and almost negligible in the Boerner (99.5510 to 103.5111 g.). In the case of the modified halving, the working sample weights obtained from the tray (numbers one to four) were much bigger than were those obtained from the pan (numbers five to eight).

The results of testing another mixture of big free flowing seeds are shown in table 6. Among the three dividers studied, the Boerner gave better results than did the big Kopooshian or the modified halving. All the working samples drawn from the Boerner were non-significant, whereas, working sample number seven of the big Kopooshian and number six of the modified halving were significant. The total chi-square values show that the big Kopooshian and the modified halving gave similar results with this mixture.

The range of the weights of the working samples in case of the Boerner was from 95.8896 to 104.1096 g. and from 94.3114 to 109.0802 g. for the big Kopooshian. A wider range of 78.9421 to 117.0121 g. was

Table 5. Subsample weight, individual chi-square of the different components, and total chi-square values of mixture 3, for different dividers.

Divider	Subsample Number	Subsample Weight (g)	Individual chi-square values A	B	C	D	Total chi-square values
Big Kopooshian	1	95.1806	26.5128	2.5666	0.1493	22.3226	51.5513++
	2	103.8056	14.0948	0.8429	3.1646	14.2538	32.3561++
	3	99.1456	0.3134	2.0794	0.4272	1.4700	4.2900
	4	104.3035	8.7834	2.1613	0.1350	7.9373	19.0170++
	5	93.8066	0.0088	0.7248	0.6099	0.0214	1.3649
	6	107.8413	16.3848	0.1468	3.6500	17.0088	37.1904++
	7	102.2682	4.6061	2.1734	1.2414	2.2193	10.2402+
	8	107.0664	10.3761	0.4596	0.5617	6.6092	18.0066++
Boerner	1	103.5111	1.3399	0.0010	0.0035	0.7512	2.0956
	2	102.6521	3.0111	1.1776	0.7588	0.6705	5.6180
	3	101.6801	1.0458	4.1518	0.0006	0.0062	5.2044
	4	101.1243	0.0113	6.2584	1.1406	1.0484	8.4587+
	5	102.1005	0.0071	0.4380	0.5589	0.0345	1.0385
	6	102.6961	4.0177	3.9534	1.9240	3.7951	13.6902++
	7	101.9831	0.8924	5.0432	0.0131	0.0006	5.9493
	8	99.5510	0.0025	0.7315	0.0465	0.0962	0.8767
Modified halving	1	118.4961	1.1283	0.0025	0.0536	0.6596	1.8440
	2	126.6500	21.0626	1.0329	0.2765	17.9670	40.3390++
	3	116.9298	2.4297	0.4338	0.4370	1.2777	4.5782
	4	124.9889	6.9303	0.0001	0.1405	4.8182	11.8891++
	5	82.8466	4.8035	0.8516	2.4754	4.0768	12.2073++
	6	84.3401	0.9407	1.0015	0.7958	1.1572	3.8952
	7	82.7205	0.4979	0.4335	4.1327	1.8684	6.9325
	8	80.5474	0.2913	0.0520	4.9192	0.0023	5.2648

Mixture 3: A = Vicia sativa 75% (600.0 g)

B = Lens esculentus 15% (80.0 g)

C = Triticum durum 5% (80.0 g)

D = Melilotus alba 5% (40.0 g)

Subsample weight A + B + C + D = 100.0 g.

+ Significant at 5% level

++ Significant at 1% level

Table 6. Subsample weight, individual chi-square of the different components, and total chi-square values of mixture 4, for different dividers.

Divider	Subsample Number	Subsample Weight (g)	Individual chi-square values A	B	C	D	Total chi-square values
Big Kopooshian	1	99.9866	0.1174	1.0479	2.9448	0.6650	4.7751
	2	94.3114	0.0227	1.3576	2.7335	1.0923	5.2061
	3	97.3283	1.9924	2.3786	1.7203	0.3754	6.3667
	4	104.6421	1.4463	1.7908	1.8083	1.0519	6.0973
	5	96.1066	0.2965	1.2169	2.9097	0.0037	4.4268
	6	109.0802	0.0028	0.0804	0.0875	0.0004	0.1711+
	7	95.8498	0.1454	1.8971	4.9154	1.2181	8.1760
	8	96.5561	1.4252	0.3196	3.7932	0.2871	5.8751
Boerner	1	97.6899	0.0737	0.9688	1.2044	0.0182	2.2651
	2	98.6911	0.0279	0.1270	0.1886	3.3592	3.7027
	3	104.1096	0.3843	0.0024	0.0612	1.4906	1.9385
	4	99.9561	0.1101	0.0529	0.2673	0.0809	0.5112
	5	95.8896	0.1239	1.3223	0.8945	0.7927	3.2334
	6	100.9852	1.4283	1.0679	0.1346	1.5340	4.1648
	7	100.6002	0.0385	0.6178	0.3460	0.3089	1.3112
	8	101.0104	0.0000	2.7288	0.9191	0.2836	3.9315
Modified halving	1	83.6224	0.1906	1.0797	0.4171	2.3723	4.0597
	2	83.6067	1.5029	0.0085	4.2869	0.2972	6.0955
	3	78.9421	1.1895	0.8746	0.2204	0.7877	3.0722
	4	83.4224	0.0906	0.0561	0.0412	0.0150	0.2029
	5	115.8245	0.0602	0.3514	0.0923	1.0039	1.5078+
	6	115.5472	1.3078	0.0423	5.0966	1.5761	8.0228
	7	117.0121	0.0612	0.7857	1.0902	0.0002	1.9373
	8	115.9196	0.4174	1.5830	0.0941	0.2531	2.3476

Mixture 4: A = Triticum durum 75% (600.0 g)

B = Sorghum vulgare 10% (80.0 g)

C = Trifolium subterraneum 5% (80.0 g)

D = Hordeum vulgare 10% (40.0 g)

Subsample weight A + B + C + D = 100.0 g.

$^{+}$ Significant at 5% level
$^{++}$ Significant at 1% level

obtained for the modified halving. Also, the modified halving showed large differences between weights of the working samples obtained from the tray (numbers one to four) and those of the pan (numbers five to eight).

The study of the three dividers for the two mixtures of big free flowing seeds indicated that the Boerner was better in yielding representative working samples than were either the big Kopooshian or the modified halving. In one of the two mixtures, the modified halving gave slightly better results than did the big Kopooshian. In the other, however, both methods gave similar results.

The modified halving showed poor results as far as the weights of the working samples were concerned. All the working sample weights obtained by the modified halving were far from the expected weight of 100.0 g.

Mixtures of Small Chaffy Seeds

The big or small Kopooshian, the Gamet, and the modified halving were studied with respect to three different mixtures of small chaffy seeds.

The big Kopooshian was chosen for the mixture 7 and 8 instead of the small Kopooshian because the channels of the latter are small for the seeds of *Bromus inermis* and *Agropyron elongatum* present in these mixtures.

It can be seen from the results presented in Table 7 that five working samples obtained from the big Kopooshian were significant at the 1% level and two at the 5% level. Similar results were obtained for the modified halving. With reference to the Gamet, four working samples were highly significant. Accordingly, neither of these methods

Table 7. Subsample weight, individual chi-square of the different components, and total chi-square values of mixture 5, for different dividers.

Divider	Subsample Number	Subsample Weight (g)	Individual chi-square values A	B	C	D	Total chi-square values
Big Kopooshian	1	6.8771	3.7070	3.6739	9.3644	1.4175	18.1628^{++}
	2	7.4497	5.5709	4.1770	12.3525	1.6091	93.7095^{++}
	3	7.3561	5.2512	0.2735	3.5965	0.0747	9.1959^{+}
	4	8.2831	12.1263	0.1250	15.2271	11.5074	38.9858^{++}
	5	6.7191	0.5079	1.4426	3.7920	6.1050	11.3905^{++}
	6	7.2285	0.6258	1.1233	2.7338	3.7931	8.2760^{+}
	7	7.3121	0.3430	0.4260	3.4292	9.1336	13.3318^{++}
	8	8.6229	1.2300	0.0140	0.0329	0.9724	2.2494
Gamet	1	7.0942	1.1841	2.8469	0.8607	0.7452	5.6369
	2	6.8691	12.2734	0.3397	5.7509	0.1630	18.5270^{++}
	3	7.3411	30.9499	1.8356	16.1093	0.0196	48.9144^{++}
	4	7.6472	11.9890	0.1089	26.0986	9.4940	47.6905^{++}
	5	7.6554	0.1894	0.4287	2.2194	1.7002	4.5377
	6	7.0021	1.5494	0.8656	0.4794	0.0005	2.8959
	7	7.6161	0.1474	0.0010	0.0053	0.2919	0.4456
	8	7.6061	9.2477	0.9009	4.7825	0.0001	14.9312^{++}
Modified halving	1	7.5173	19.0454	13.0024	50.2120	10.6902	92.9500^{++}
	2	7.2502	4.6365	7.1838	26.4092	12.4490	50.6785^{++}
	3	7.5877	5.3673	0.0000	4.5539	0.1088	10.0302^{+}
	4	7.6391	3.2775	0.1190	9.4068	5.8917	18.6950^{++}
	5	7.8466	0.8749	3.9551	7.1069	3.0797	15.0166^{++}
	6	7.5695	3.1201	2.9389	0.6753	0.0051	6.7394
	7	7.6894	13.0518	0.0015	34.1809	16.8127	64.0469^{++}
	8	7.3332	4.8926	3.6574	1.8847	0.0832	10.5179^{+}

Mixture 5: A: *Agropyron elongatum* 70% (42.0 g)

B: *Festuca arundinacea* 5% (3.0 g)

C: *Cynodon dactylon* 5% (3.0 g)

D: *Lolium multiflorum* 20% (12.0 g)

Subsample weight A + B + C + D = 7.5 g.

$^{+}$ Significant at 5% level

$^{++}$ Significant at 1% level

for obtaining the working samples was dependable.

The range of variation among the working samples obtained from the big Kopooshian was from 6.7191 to 8.6229 g. In the Gamet, the range was from 6.8691 to 7.6554 g. and in the case of the modified halving it was from 7.2502 to 7.8466 g. This shows that the Gamet and the modified halving did a good job in dividing this seed mixture when compared to that of the big Kopooshian.

In the modified halving, the variation among the weights of the working samples is small compared to that between samples from the big Kopooshian, although most of the samples were not significantly different. The reason for this might be the unequal distribution of the different components in the working samples obtained from the synthetic mixture by the big Kopooshian.

It can be seen from the data in table 8 that the big Kopooshian gave six highly significant chi-square values, the Gamet gave four highly significant and two significant, and the modified halving gave seven highly significant and one non-significant. In summary, all three of the dividers did a poor job of mixing this sample.

In most of the cases higher chi-square values in different dividers were obtained because of the unequal distribution of one or more of the components of the mixtures in the different working samples.

In the case of the modified halving, high chi-square values in most cases were contributed mainly by the component *Cynodon dactylon*. The reason might be the unequal distribution of this seed due to the fact that it is the smallest sized seed among the different components of the mixture.

Table 8. Subsample weight, individual chi-square of the different components, and total chi-square values of mixture 6, for different dividers.

Divider	Subsample Number	Subsample Weight (g)	Individual chi-square values A	B	C	D	Total chi-square values
Big Kopooshian	1	4.7081	6.6710	0.1033	2.6154	22.6752	32.0649^{++}
	2	4.8766	6.1146	0.2704	1.7146	11.3807	19.4803^{++}
	3	4.5771	5.3576	1.1984	0.3679	14.8566	21.7805^{++}
	4	4.8271	5.8420	0.0211	3.9421	18.8152	28.6204^{++}
	5	5.1161	7.4443	3.6529	4.1385	13.1491	28.3848^{++}
	6	4.9665	2.0711	0.7923	2.0673	0.4368	5.3675
	7	5.7666	11.4089	3.4409	0.6873	11.4242	26.9613^{++}
	8	5.0478	1.1392	0.0511	0.0407	1.9359	3.1669
Gamet	1	5.0961	5.1301	2.2978	5.2358	10.6784	23.3421^{++}
	2	4.8280	0.9261	1.1546	0.2449	2.8405	5.1661
	3	5.1097	23.3907	0.9472	13.9053	25.5171	63.7603^{++}
	4	4.1315	15.0342	3.4046	3.9729	13.7332	36.1449^{++}
	5	5.0205	3.2673	0.2586	1.9850	5.0025	10.5134^{+}
	6	4.9184	2.2244	1.9203	3.6381	0.0360	7.8188^{+}
	7	5.2516	10.3835	0.0668	7.1658	14.1823	31.7984^{++}
	8	5.0914	0.2297	0.2483	2.6735	0.0008	3.1523
Modified halving	1	5.5972	41.6468	10.7260	0.4941	164.2542	217.1211^{++}
	2	4.8971	0.0201	0.6730	0.1224	1.8198	2.6353
	3	4.9335	24.9862	0.2919	3.7695	153.0864	232.1340^{++}
	4	4.9852	8.3164	0.9059	2.8027	24.6004	36.6254^{++}
	5	5.2791	0.0110	4.5226	0.7999	6.0462	11.3797^{++}
	6	4.9469	27.7507	1.6404	13.1731	31.2575	73.8217^{++}
	7	5.0291	4.3654	0.1278	3.7552	3.4294	11.6778^{++}
	8	4.4901	53.2104	2.0908	6.5563	126.9807	188.8382^{++}

Mixture 6: A = *Bromus inermis* 70% (28.0 g)

B = *Lolium multiflorum* 20% (8.0 g)

C = *Phalaris tuberosa* 5% (2.0 g)

D = *Cynodon dactylon* 5% (2.0 g)

Subsample weight A + B + C + D = 5.0 g.

$^{+}$ Significant at 5% level

$^{++}$ Significant at 1% level

As shown by the data (table 9), the small Kopooshian gave the best results of mixing as all the chi-square values are non-significant. Modified halving was slightly better than the Gamet.

The variation in the working samples weights was negligible ranging from 4.4253 to 5.3105 g. for the small Kopooshian, 4.7471 to 5.3994 g. in the Gamet and 4.7224 to 5.2805 g. in the modified halving.

From this study it can be noticed that the big Kopooshian, the Gamet, and the modified halving all did a poor job of mixing and dividing the seed mixtures which had either Agropyryon elongatum or Bromus inermis as the major component. On the other hand, the small Kopooshian did a good job, with the modified halving and the Gamet ranking next, in mixing and dividing the seed mixture which had Lolium multiflorum as the major component.

Mixtures of Big Chaffy Seeds

Only the Boerner and the big Kopooshian dividers were used in the comparative study of drawing working samples from two synthetic mixtures of big chaffy seeds.

A study of the results presented in table 10 indicated that the Boerner is slightly better in mixing than the big Kopooshian in that the latter has three chi-square values highly significant and one is significant whereas the former shows only one chi-square value as significant.

The range of working sample weights in case of the big Kopooshian were from 94.8180 to 105.7455 g. which is slightly greater than that of the Boerner which ranges from 97.1231 to 101.4824 g.

The results of another mixture of big chaffy seeds are given

Table 9. Subsample weight, individual chi-square of the different components, and total chi-square values of mixture 7, for different dividers.

Divider	Subsample Number	Subsample Weight (g)	Individual chi-square values A	B	C	D	Total chi-square values
Small Kopooshian	1	4.9202	0.2521	0.3845	0.7881	2.7027	4.1274
	2	4.9317	0.6873	0.8973	1.3748	1.0162	3.9756
	3	4.8244	0.3794	0.0384	0.4250	1.5892	2.4320
	4	5.2437	1.1495	0.0877	6.1995	0.0829	7.5160
	5	4.7481	1.6751	0.5273	1.7967	0.1419	4.1410
	6	5.1291	0.3747	0.0741	0.1988	1.6161	2.2637
	7	5.3105	0.5080	0.0292	1.1530	0.1401	1.8303
	8	4.4253	0.4681	0.2222	3.9396	0.6467	5.2766
Gamet	1	4.7989	0.8358	5.0446	1.2251	2.0380	9.1435+
	2	4.7471	1.6701	2.2106	0.0477	0.0428	3.9712
	3	4.8967	0.4066	0.3945	4.3618	0.8477	6.0106
	4	4.8513	0.7553	0.0072	12.9543	1.7094	15.4262++
	5	4.9858	0.9123	0.7894	1.4718	2.2570	5.4305
	6	4.8312	1.6333	4.5290	8.4647	22.3047	36.9319++
	7	5.3994	0.0782	0.0153	1.4979	0.0300	1.6214
	8	5.1845	0.0509	0.1301	0.7722	0.9487	1.9029
Modified halving	1	4.8423	0.5265	0.8184	0.0045	0.0053	1.3457
	2	4.8261	0.8414	3.5542	0.3842	1.2547	6.0345
	3	5.1117	0.1003	0.1278	0.2700	0.1931	0.6992
	4	5.2805	0.1033	0.0456	0.2268	0.5821	0.9578
	5	5.0865	0.4981	0.5375	0.0386	0.1156	1.1898
	6	4.7224	0.1158	2.0849	0.0371	3.8081	6.0469
	7	4.8979	5.4551	2.6243	0.0357	4.0618	12.1769++
	8	5.1211	0.0222	2.4407	2.0812	2.3647	6.9088

Mixture 7: A = *Lolium multiflorum* 50% (20.0 g)

B = *Festuca arundinacea* 40% (16.0 g)

C = *Melilotus indica* 5% (2.0 g)

D = *Lotus corniculatus* 5% (2.0 g)

Subsample weight A + B + C + D = 5.0 g.

+ Significant at 5% level

++ Significant at 1% level

Table 10. Subsample weight, individual chi-square of the different components, and total chi-square values of mixture 8, for different dividers.

Divider	Number	Subsample Weight (g)	Individual chi-square values A	B	C	D	Total chi-square values
Big Kopooshian	1	97.7889	10.7565	3.5306	7.7487	0.0352	22.0710++
	2	101.1016	0.6430	6.1049	1.9043	0.6521	9.3043+
	3	99.5501	2.2232	0.1229	1.1650	0.6311	4.1422
	4	103.5133	2.1604	0.0561	0.8692	1.3620	4.4477
	5	105.7455	0.4323	3.5170	0.6824	0.0216	4.6533
	6	94.8180	10.1250	0.9931	7.1573	0.2600	18.5354++
	7	99.0011	6.1622	1.1834	9.5326	0.8632	17.7414++
	8	98.2010	0.0025	3.3188	0.0754	0.0246	3.4213
Boerner	1	101.1694	1.6811	2.1024	0.4848	2.0433	6.3116
	2	98.9951	0.3765	3.5675	0.0042	0.6948	4.6430
	3	99.0874	0.8013	5.9076	0.1600	3.9254	10.7943+
	4	97.1231	0.9455	0.3356	0.7968	0.0765	2.1544
	5	101.4824	1.7834	0.6896	1.1913	0.3838	4.0481
	6	100.6811	0.0294	0.9521	0.1877	0.5985	1.7677
	7	100.7811	2.7425	0.1094	0.9541	0.0021	3.8081
	8	97.4884	0.3033	0.0013	1.0163	0.3400	1.5619

Mixture 8: A = Hordeum vulgare 75% (600.0 g)

B = Sorghum vulgare 10% (80.0 g)

C = Melilotus alba 5% (80.0 g)

D = Triticum durum 10% (40.0 g)

Subsample weight A + B + C + D = 100.0 g.

Note - Modified halving was not used as the compartment of the divider was smaller than the major component of the mixture (Hordeum vulgare).

+ Significant at 5% level

++ Significant at 1% level

in Table 11. The Boerner and the big Kopooshian did a very poor job in mixing as all chi-square values are highly significant. This is contrary to the results obtained in mixture number 8.

In most of the cases, the mixture component Melilotus indica contributed to high chi-square values for both the dividers. This might be due to the unequal distribution of this component.

The variation in the working sample weights was large in the case of the big Kopooshian, ranging from 90.7795 to 106.276 g., whereas, in the case of the Boerner, the range was relatively small, 97.5104 to 100.9216 g.

Table 11. Subsample weight, individual chi-square of the different components, and total chi-square values of mixture 9, for different dividers.

Divider	Subsample Number	Subsample Weight	Individual chi-square values A	B	C	D	Total chi-square values
Big Kopooshian	1	106.2762	20.6093	9.9165	0.0101	141.2651	171.8010++
	2	97.9801	3.7318	3.1112	0.6492	91.0377	98.5299++
	3	102.8945	21.7722	0.4286	0.4419	158.1097	180.7524++
	4	99.9744	2.5436	6.1468	0.0738	88.3017	97.0659++
	5	90.8061	5.3190	5.8383	1.1996	30.2569	42.6138++
	6	90.7795	0.2080	2.2414	0.0001	55.9333	58.3828++
	7	98.0012	13.6757	9.968	0.0579	21.8786	45.5890++
	8	92.1871	1.6034	5.5212	1.7501	16.9411	25.8158++
Boerner	1	97.5104	16.1183	5.5362	1.6134	17.0512	40.3191++
	2	93.7186	0.0761	5.2111	3.0960	73.3171	81.7003++
	3	97.8627	1.1194	2.8567	0.1080	48.7962	52.8803++
	4	100.9216	1.3129	1.5195	3.6639	58.8006	65.2969++
	5	95.0184	0.0054	5.4228	2.2269	70.1577	77.8128++
	6	99.8210	2.6352	9.9983	1.0270	74.0597	87.1202++
	7	98.5401	0.6819	8.3205	0.4375	76.4163	85.8562++
	8	100.8557	0.0357	0.0017	2.2695	69.5893	71.8962++

Mixture 9: A = *Avena sativa* 75% (600.0 g)

B = *Triticum durum* 10% (80.0 g)

C = *Hordeum vulgare* 10% (80.0 g)

D = *Melilotus indica* 5% (40.0 g)

Subsample weight A + B + C + D = 100.0 g.

Note: Modified halving was not used as the compartments were smaller than the major component of the mixture (*Avena sativa*).

+ Significant at 5% level
++ Significant at 1% level

SUMMARY

Individual and comparative studies of the small and big Kopooshian, the Gamet, the Boerner, and the modified halving were made at the Seed Technology Laboratory of the American University of Beirut. Nine synthetic mixtures of different kinds and sizes of seeds were used for mixing and dividing to obtain the working samples. A statistical method of chi-square test was employed to judge the efficiency of the dividers. The following results were obtained:

1. Better mixing and dividing of the small free flowing seeds were obtained by the small Kopooshian. Although the nature of the mixtures was similar, the results obtained by the Gamet were inconsistent.

2. With respect to the big free flowing seeds, the Boerner gave more representative working samples than either the big Kopooshian or the modified halving. The chi-square values indicated that modified halving gave slightly better results than the big Kopooshian in one of the two mixtures studied. In the other mixture, however, both the modified halving and the big Kopooshian gave similarly good results.

The modified halving showed a serious drawback in dividing in that a wide range of weights of the working samples was produced when the synthetic mixtures of big free flowing seeds were tested.

3. The three dividers namely, the big Kopooshian, the Gamet, and the modified halving gave very poor results in mixing the synthetic small chaffy seed mixtures that had either *Agropyron elongatum* or *Bromus inermis* as a major component. On the other hand, the three dividers (especially the small Kopooshian) gave more uniform working

samples with the synthetic mixture that had Lolium multiflorum as the major component.

4. Where only the two dividers, the Boerner and the big Kopooshian were used for big chaffy seed mixtures, the former gave better results in one of the two mixtures studied. Both dividers gave extremely poor results with the other mixture. This may have been caused by the uneven distribution of M. indica in the mixture.

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APPENDIX

Table 12. Weights of the different components of the subsamples obtained from mixture 1 by different dividers.

Divider	Subsample Number	Weights of different components (g)			
		Melilotus indica	Trifolium repens	Medicago orbicularis	Trifolium subterraneum
Small Kopooshian	1	2.7907	1.6311	0.7496	0.5056
	2	2.7908	1.4737	0.7704	0.5651
	3	2.2366	1.1231	0.6811	0.4561
	4	2.5156	1.0511	0.7887	0.4968
	5	2.5171	1.4124	0.7771	0.4581
	6	2.3451	1.3854	0.7441	0.5371
	7	2.5347	1.2273	0.7601	0.4647
	8	2.2933	0.8071	0.7614	0.5503
Gamet	1	2.7537	1.5551	0.9652	0.6141
	2	2.6885	1.1381	0.8577	0.5337
	3	2.4387	1.3911	0.7066	0.4645
	4	2.3355	1.1152	0.6737	0.4861
	5	2.3242	1.2131	0.6502	0.4191
	6	2.3197	1.0404	0.6611	0.4847
	7	2.5941	1.1547	0.8705	0.6066
	8	2.6231	1.4261	0.8014	0.4521
Modified halving	1	2.6943	1.3571	0.7851	0.4445
	2	2.5311	1.2096	0.7088	0.4437
	3	2.5664	1.2637	0.7871	0.5544
	4	2.4171	1.2683	0.8297	0.3968
	5	2.5241	1.2284	0.8106	0.6022
	6	2.4931	1.2701	0.7202	0.4934
	7	2.4741	1.2821	0.7101	0.5301
	8	2.3685	1.2911	0.7785	0.4894

Table 13. Weights of the different components of the subsamples obtained from mixture 2 by different dividers.

Divider	Subsample Number	Weights of different components (g)			
		Trifolium pratense	*T. subterraneum*	*Lotus corniculatus*	*Melilotus indica*
Small Kopooshian	1	3.4235	0.6448	0.4794	0.2435
	2	3.2651	0.6055	0.4674	0.2831
	3	3.3708	0.7861	0.4501	0.2142
	4	3.2059	0.7511	0.4415	0.2264
	5	3.3836	0.7411	0.4971	0.2196
	6	3.5943	0.6535	0.4756	0.1921
	7	3.7688	0.7828	0.5334	0.2797
	8	3.5811	0.8044	0.4964	0.2799
Gamet	1	3.6985	0.5867	0.5197	0.2576
	2	2.9141	0.4391	0.4655	0.2103
	3	3.6373	0.7264	0.5033	0.2686
	4	3.1571	0.7544	0.4627	0.2334
	5	3.6804	0.7138	0.5166	0.3108
	6	3.5076	0.7282	0.5492	0.2913
	7	4.0506	1.0681	0.5681	0.3198
	8	2.8481	0.7801	0.4631	0.1907
Modified halving	1	3.0861	0.5923	0.4371	0.2365
	2	3.5677	0.7001	0.5391	0.2778
	3	3.4605	0.7526	0.4948	0.2975
	4	3.5451	0.7097	0.5466	0.2531
	5	3.3331	0.7182	0.5241	0.2598
	6	3.6481	0.7684	0.5145	0.2314
	7	3.6276	0.8451	0.5411	0.2533
	8	3.3155	0.6541	0.5091	0.2389

Table 14. Weights of the different components of the subsample obtained from mixture 3 by different dividers.

Divider	Subsample Number	Weights of different components (g)			
		Vicia sativa	Lens esculentus	Triticum durum	Melilotus indica
Big Kopooshian	1	71.1126	15.8501	4.6059	4.3121
	2	78.2451	15.1426	5.5883	4.3831
	3	75.0891	13.8331	4.7356	5.1851
	4	78.6804	16.0181	4.8051	4.5931
	5	70.6725	13.3036	5.0473	4.7021
	6	79.4857	17.0581	4.8264	6.2655
	7	75.8541	16.0725	4.2698	4.9402
	8	81.9011	14.5431	5.4141	4.7901
Boerner	1	78.1335	15.2118	5.0251	4.9651
	2	78.8441	14.0911	4.6151	4.9481
	3	78.2227	13.3171	5.0632	5.0684
	4	73.8104	17.0261	5.3974	4.7904
	5	75.7826	15.7875	5.4058	5.0293
	6	77.1417	16.5354	4.2356	4.6924
	7	77.5381	13.0204	5.0951	5.0435
	8	75.2125	14.1961	5.0963	5.0261
Modified halving	1	89.4314	17.3927	5.9261	5.7181
	2	96.6351	18.5375	6.0986	5.3588
	3	88.8321	16.4747	6.0414	5.5816
	4	95.1331	17.9426	6.1731	5.7321
	5	60.9601	13.7097	3.6011	4.4893
	6	63.1641	12.0641	4.7016	4.4101
	7	62.7451	12.1928	3.3556	4.3791
	8	61.1486	12.2271	3.0601	4.0117

Table 15. Weights of the different components of the subsamples obtained from mixture 4 by different dividers.

Divider	Subsample Number	Weights of different components (g)			
		Triticum durum	Sorghum vulgare	Trifolium subterraneum	Hordeum vulgare
Big Kopooshian	1	74.5356	10.3555	4.6081	10.4231
	2	70.0625	9.8603	4.3542	10.0153
	3	71.9206	10.6943	5.2118	9.5004
	4	79.0721	9.5737	4.8666	10.9735
	5	71.9692	9.1901	5.1781	9.6821
	6	81.8594	10.7811	5.5214	10.9404
	7	72.4771	9.0838	5.2871	8.9821
	8	73.2493	9.7516	4.3851	9.1081
Boerner	1	73.2674	9.3525	5.1206	9.9264
	2	73.0741	9.6091	4.8111	11.0621
	3	78.2771	10.2567	5.0936	9.4032
	4	75.2621	10.0661	4.8797	9.7492
	5	71.5738	9.0703	4.9871	10.2424
	6	77.3687	9.5097	4.9414	9.1411
	7	75.6154	10.4218	4.9061	9.6364
	8	75.5341	10.8891	4.8551	9.6896
Modified halving	1	61.9107	7.8834	4.2864	9.3452
	2	63.0195	8.0886	3.7157	8.4751
	3	60.1734	7.3781	3.8152	7.2297
	4	62.6681	8.1811	4.1091	8.2064
	5	85.9754	11.2131	5.8245	12.2847
	6	86.1524	11.9022	6.3541	10.8246
	7	87.4511	12.0651	5.5864	11.6031
	8	86.0965	12.3211	5.8869	11.2631

Table 16. Weights of the different components of the subsamples obtained from mixture 5 by different dividers.

Divider	Subsample Number	Weights of different components (g)			
		Agropyron elongatum	Festuca arundinacea	Cynodon dactylon	Lolium multifolium
Big Kopooshian	1	4.8621	0.3791	0.2938	1.3644
	2	5.2563	0.4067	0.3101	1.4591
	3	5.3107	0.3335	0.3311	1.4191
	4	5.8696	0.3881	0.3111	1.7093
	5	4.5817	0.3644	0.3106	1.4621
	6	5.0761	0.3191	0.3356	1.5264
	7	4.9837	0.3825	0.3441	1.6361
	8	6.1713	0.4201	0.4235	1.6386
Gamet	1	5.0474	0.2947	0.3375	1.4391
	2	4.9697	0.2956	0.2901	1.2317
	3	5.4231	0.2801	0.2811	1.2751
	4	5.3815	0.3503	0.2896	1.5461
	5	5.2701	0.3901	0.3551	1.5631
	6	4.9531	0.3095	0.3315	1.3531
	7	5.2346	0.3787	0.3782	1.5495
	8	5.0543	0.4315	0.4261	1.6074
Modified halving	1	5.2944	0.4300	0.2551	1.4881
	2	4.9938	0.4086	0.2791	1.5246
	3	5.3971	0.3551	0.3341	1.4451
	4	5.2817	0.4115	0.4355	1.4538
	5	5.4162	0.4361	0.3464	1.6067
	6	5.1204	0.4428	0.3981	1.5616
	7	5.2714	0.4238	0.4931	1.4401
	8	4.9496	0.4421	0.3974	1.5131

Table 17. Weights of the different components of the subsamples obtained from mixture 6 by different dividers.

Divider	Subsample Number	Weights of different components (g)			
		Bromus inermis	Lolium multiflorum	Phalaris tuberosa	Cynodon dactylon
Big Kopooshian	1	3.2802	0.9601	0.2725	0.2015
	2	3.4126	1.0117	0.2278	0.2234
	3	3.0901	0.9451	0.2181	0.1971
	4	3.3069	0.9487	0.2825	0.2078
	5	3.6637	0.9572	0.3108	0.2378
	6	3.4916	0.9861	0.2363	0.2586
	7	4.1794	1.0921	0.2885	0.2735
	8	3.5321	1.0628	0.2656	0.2571
Gamet	1	3.5521	1.1084	0.2198	0.2354
	2	3.3068	1.0388	0.2433	0.2381
	3	3.7297	0.9811	0.1913	0.2191
	4	3.4288	0.8721	0.2091	0.2148
	5	3.4934	1.0495	0.2351	0.2427
	6	3.4755	0.9553	0.2257	0.2613
	7	3.7156	1.0731	0.2187	0.2377
	8	3.5011	1.0801	0.2381	0.2708
Modified halving	1	3.6534	1.0821	0.3398	0.4518
	2	3.3395	0.9777	0.2545	0.2734
	3	3.6354	0.9027	0.2021	0.1331
	4	3.3271	1.0265	0.3093	0.3213
	5	3.6781	1.0091	0.2693	0.3106
	6	3.6171	0.9256	0.1841	0.2047
	7	3.5318	1.0103	0.2261	0.2475
	8	3.2576	0.9146	0.1721	0.1261

Table 18. Weights of the different components of the subsamples obtained from mixture 7 by different dividers.

Divider	Subsample Number	Weights of different components (g)			
		Lolium multiflorum	Festuca arundinacea	Melilotus indica	Lotus corniculatus
Small Kopooshian	1	2.3781	1.8884	0.2602	0.2716
	2	2.4344	1.8287	0.2134	0.2553
	3	2.4112	1.9525	0.2597	0.2691
	4	2.3485	1.9658	0.2948	0.2381
	5	2.3981	2.0521	0.2783	0.2571
	6	2.3681	1.9511	0.2323	0.2647
	7	2.6491	2.1781	0.2944	0.2781
	8	2.5531	2.0506	0.3035	0.2761
Gamet	1	2.5303	1.8041	0.2691	0.2721
	2	2.3334	2.0531	0.2391	0.2473
	3	2.4172	1.9384	0.1945	0.2205
	4	2.6543	2.0606	0.1821	0.2831
	5	2.2719	1.9377	0.2101	0.2614
	6	2.4916	1.9166	0.3217	0.3481
	7	2.6392	2.1017	0.2357	0.2651
	8	2.2026	1.7235	0.2016	0.2355
Modified halving	1	2.3466	1.9859	0.2391	0.2391
	2	2.4625	1.7784	0.2521	0.2592
	3	2.5531	1.9954	0.2421	0.2611
	4	2.6043	2.0874	0.2735	0.2776
	5	2.4442	2.0524	0.2461	0.2564
	6	2.3866	1.7855	0.2402	0.2711
	7	2.2789	2.0854	0.2503	0.2831
	8	2.5681	1.9291	0.2864	0.2844

Table 19. Weights of the different components of the subsamples obtained from mixture 8 by different dividers.

Divider	Subsample Number	Weights of different components (g)			
		Hordeum vulgare	Sorghum vulgare	Melilotus alba	Triticum durum
Big Kopooshian	1	74.8711	9.5441	4.3205	9.0501
	2	75.3713	10.4935	4.7861	10.3837
	3	75.3201	9.3111	4.7269	10.1902
	4	78.6195	9.4446	4.9578	10.8914
	5	79.3355	10.7655	5.1191	10.5054
	6	69.6613	10.0531	5.3265	9.7681
	7	74.0861	9.4341	5.5851	9.8925
	8	73.3061	10.1276	4.8671	9.8911
Boerner	1	77.1557	10.1142	4.9081	8.9914
	2	72.4343	10.1871	4.9017	10.3711
	3	71.9911	10.4581	4.8751	11.1516
	4	72.0833	9.6076	5.0194	10.0451
	5	76.5111	9.7261	4.8221	10.2733
	6	75.1076	9.9891	5.0735	9.5351
	7	75.9381	9.3396	4.7566	9.7341
	8	73.3121	9.4021	5.0592	9.5871

Table 20. Weights of different components of the subsamples obtained from mixture 9 by different dividers.

Divider	Subsample Number	Weights of different components (g)			
		Avena sativa	Triticum durum	Hordeum vulgare	Melilotus indica
Big Kopooshian	1	83.3307	8.0481	10.1141	4.7833
	2	75.5804	8.5131	9.1176	4.7491
	3	79.0205	9.1864	10.0751	4.4125
	4	76.3877	8.1935	10.0381	4.8551
	5	68.5586	7.9667	8.7978	5.0835
	6	68.5584	8.2367	9.1921	4.6923
	7	73.1108	8.2855	10.2831	5.6758
	8	68.8631	8.3591	9.0401	5.4361
Boerner	1	73.0745	8.1544	10.8855	4.8384
	2	70.4823	8.4624	9.3451	4.9461
	3	71.9955	8.9755	11.1323	4.9994
	4	76.0374	8.5491	11.1855	5.1091
	5	73.4581	7.4226	8.7971	4.7431
	6	75.8585	7.9925	10.3911	4.9635
	7	74.3175	9.8216	8.7871	4.9596
	8	75.8064	7.9931	10.3915	4.9601