5-1951

Pellet Seeding on Sagebrush Range

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PELLET SEEDING ON SAGEBRUSH RANGE

by

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A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Range Management

1951

UTAH STATE AGRICULTURAL COLLEGE
Logan, Utah

ACKNOWLEDGEMENT

I wish to express sincere appreciation to Dr. L. A. Stoddart and Dr. C. W. Cook for helpful suggestions pertaining to this study and in the preparation of this manuscript; to Professor Bliss Crandall for guidance in making a statistical analysis of the data; and to Mr. H. J. Burback of the Bureau of Land Management who made materials available for this study.

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INTRODUCTION

Seeding deteriorated range lands efficiently and economically has become one of the most promising means of improving the agricultural economy of the western range states. By providing the most rapid means of increasing the quantity and improving the quality of forage for livestock, and aiding in the prevention of soil erosion, artificial seeding contributes directly to the stability of agriculture.

Although many successful methods of artificial revegetation have been developed by experience and through research, there is still a great need for refinement in techniques to insure better overall success and greater economy of operation. Improper methods often result in costs which are in excess of the true value of the land.

One of the latest techniques proposed is that of pellet seeding which is believed by some stockmen to be the panacea for range seeding problems. Pelleting is an attempt to prepare seeds for broadcast planting to get more even seed distribution; increased germination and growth; and protection from drought, insects, and rodents.

Actual seeding of ranges should be preceded by extensive experimentation to determine the effectiveness of a proposed technique. However, considering the increased use of pellet seeding and the enthusiasm with which it has been received, too little actual experimental work has been accomplished to warrant widespread acceptance of this method.

The present study was undertaken to determine the seedling emergence and survival from pellets, as compared to unpelleted seeds, when planted on a typical Intermountain foothill range.

REVIEW OF LITERATURE

It is only in recent years that attention has been focused on the use of pelleted seeds as a means of seeding range lands and that a limited literature on the subject has been made available. Because this literature deals with experiments still in the trial-and-error stage, no final statements or conclusions have been made as to the effectiveness of the pelleting process in general.

Perhaps the most publicized method of reseeding vast range areas has been aerial pellet seeding. As Killough (11) points out, the initial work in the use of airplanes for range reseeding quickly indicated that this method was the fastest known means of broadcasting bare seed and that it could be used on otherwise unworkable areas. A number of problems were soon evident, however, as the results were far below expectations. It was found that the wind and air currents scattered the seed, thus preventing it from falling on the intended area. Pilots were unable to cover an area without passing over the same course twice or leaving unseeded gaps. Much of the seed, being on the surface of the ground, was washed or blown away, or was consumed by birds, insects, and rodents. Pellet seeding has been an attempt to eliminate some of these problems.

Three commercial companies, each claiming origination of the pellet process, initiated the manufacture of a seed coating which would enable the seeding of range areas to be accomplished more economically and efficiently. These three companies are the Processed Seeds, Inc. of Midland, Michigan, the Filtrol Corporation of Los Angeles, California, and the International Seed Pellet Company of Phoenix, Arizona (13).

Dr. Lytle S. Adams of the International Seed Pellet Company devised an earthen-type pellet which supposedly provides weight for better distribution in airplane seeding; protects seed from drought, insects, and rodents; and stimulates germination and growth when environmental conditions are favorable. Each pellet consists of a few selected dehusked and scarified seeds imbedded in pulverized earth taken from the area to be planted. To this earthen pellet is added an insecticide, fungicide, rodent repellent, and fertilizer. The pellet is made by a pressure process whereby the seed is mixed to the proper proportion with clay on a rotating screen, then fed by hand into the hopper of the pelleting machine which is powered by a large diesel engine. The pellets are molded under great pressure by means of a double set of precision-geared pellet wheels located below the hopper. Moisture is added just before the clay-seed mixture is fed into the pelleting wheels. A large rotating belt receives the pellets from the gears and carries them to a screen that separates them from the fragments and dirt. The rate of pelleting is from 30,000 to 50,000 per minute and up to 3 1/2 tons per hour (16). Despite the many claims Adams has made as to the effectiveness of his pellets, Murphy (13) points out that the company has shown no concern over the mechanical makeup of the pelleting material and has done very little, if any, research regarding the most desirable material to be used in the manufacture of its pellets.

A water-soluble, non-toxic plastic pellet was originated by Mr. Phelps Vogelsang of the Processed Seeds, Inc. This pellet was developed so that under growing conditions it would absorb and hold

sufficient moisture to stimulate seed germination and, at the same time, resist disintegration long enough to protect the seed from exposure. The method used in manufacturing the pellets is known as the accretion process in which the pellets are built up by adding successive layers of inert materials. The coating machine, a spherical-shaped pan, rotates at about 45 degrees from the vertical, causing the seeds to tumble over one another. Methyl cellulose (an adhesive) is added to moisten the seed, and then powdered material (feldspar or fly ash) is added as an adherent. After the coat has been dried, the process is repeated until the pellet is of desired size (16). Mr. Vogelsang (28) indicated that in the pelleting process

> "any type of ingredient in any accurate amount can be added to the coat that will best control seed and soil-born diseases, control soil insects, fertilize the seedling, stimulate the plant and add minor elements that will give a healthy seedling and increase plant growth." (p. 3)

The Filtrol Corporation employs about the same type of machinery as the Processed Seeds, Inc., but uses the highly colloidal montmorillonite (an aluminum silicate) for the coating material. The seed is tumbled about with the coating material, and water is sprayed into the mixture to furnish the moisture necessary to make the pellets. This process is continued until the pellets are of proper size. Repellents, fertilizers, and other materials can be added and the pH can be controlled (16).

In addition to the above commercial methods, the Pacific Northwest Forest and Range Experiment Station has used pressure-formed tablets of calcium carbonate, gelatin capsules, and hand-rolled and machine-rolled pellets of powdered sugar. The Crown Zellerbach Company has tried

capsules containing flowerite and vermiculite with seeds, fertilizers, growth hormones, and fungicides (16).

Numerous laboratory, greenhouse, and field experiments have been conducted by investigators to evaluate the germination of pelleted seeds, and the subsequent seedling emergence and survival. Of the many tests made of Adams' pelleted seeds as compared to the non-pelleted, the bare seeds have given significantly higher germination than Adams' pellets (2, 5, 19, 25, 29). On the other hand, Vogelsang (27), in testing germination of his own pelleted versus non-pelleted seeds, found that a majority of the various types of plastic pellets gave better results than bare seeds. From the results of this test, he suggested that the type of material to be used should be selected on the basis of weight and rate of breakdown as most pellets gave good germination.

In comparing the emergence of Adams', Vogelsang's, and Burgesser's pelleted and unpelleted seeds, other investigators have found the bare seeds to be far superior (2, 5, 13, 19, 24, 25). Murphy (13) observed, as a result of tests conducted with pelleted and unpelleted seeds at Utah State Agricultural College nursery, that the average emergence of Adams', Vogelsang's, and Burgesser's pellets was 12 percent compared to 75 percent for the unpelleted seeds.

Aerial broadcasting of Adams' pellets on numerous test projects has proved unsuccessful to date (1, 2, 5, 12, 24, 29, 30). One of the more extensive of these airplane pellet seeding projects was conducted by Wagner (29) on Indian reservations in Arizona. Early airplane seedings made on the Papago Indian Reservation showed that the

penetration of pelleted seeds into the soil was practically negligible. Samples taken from 10,000 acres seeded by Adams' pellets showed an average of 75 plants per acre. The tests on the Papago Reservation indicated a need for soil preparation in advance of seeding to preserve sufficient moisture to maintain plants once established; for coordination of local precipitation pattern with time of seeding; and for protection of recently established plants by placing newly seeded areas under management. Results on the San Carlos Indian Reservation showed an extremely poor and spotty stand of pelleted Lehmann lovegrass (Eragrostis lehmanniania) which had been drilled, and not one Lehmann lovegrass plant was found on the airplane pellet seeded area. On the Hopi and Navajo Indian Reservations, seeded to pelleted crested wheatgrass (Agropyron cristatum), there was no evidence of seedling establishment on open ground.

Experiments have shown that none of the three commercially produced pellets has been effective as a rodent repellent (3, 16, 29, 30). In laboratory studies of Adams' pelleted seeds conducted in Denver by the Wildlife Research Laboratory concerning the effects of dry-lime sulfur as a rodent repellent, it was observed that white rats readily broke up the pellets for the seed they contained (29).

Many authors point out that one of the most important factors which effects a reduction in germination of Adams' pelleted seeds is mechanical injury (1, 2, 3, 5, 9, 12, 16, 19, 24, 25, 29, 30). Wagner (29) reports that as a result of tests made by the state seed analyst at the University of Wyoming, a reduction in germination of Adams' crested wheatgrass pellets from 80 percent before to 14 percent after pelleting resulted from mechanical injury.

Tisdale (24) states that a reduction in germination, emergence, and survival could be attributed to the texture of soil used in the Adams' pellets. A physical analysis of the soil from which these pellets were made revealed the texture to be clay, although the amount of clay was the minimum needed to bring it into this textural class. The soil contained 4.5 percent of particles coarser than 2mm in diameter, which were classed as fine gravel. It has been found (29)

> "that pellets with a high proportion of coarse material are less firm, break into fragments more readily and shed 'dust' from the edges, soak up water rapidly and lose all strength and rigidity at once when wet. On the other hand, pellets made from pure clay or shale are considerably harder, even have a 'shine', are actually difficult to break when thoroughly dry, shed less 'dust' from the edges, do not fragment easily, soak up water rather slowly and retain considerable strength and rigidity even when wet." (p. 632)

Other experimenters have indicated that perhaps deterioration in storage, induced secondary dormancy, or some unknown physiological injury have reduced germination of Adams' pelleted seeds (5, 19).

In field experiments conducted by Tisdale (24), the Vogelsang pellets showed better emergence and survival than Adams' pellets made at Gooding, Idaho. They were almost entirely free from mechanical injury to the seed and gave more prompt germination than the Adams' pellets. The main defect of Vogelsang's pellets seemed to be a tendency to break down too readily when wetted.

Because the majority of the more extensive experiments cited above have been conducted with pellets manufactured by the International Seed Pellet Company, it may not be fair, at this time, to condemn the practice entirely. However, the Adams' pellets have not proved adequate. Pellets made by the accretion method have not shown up well

in field tests, but their use has been restricted; hence their efficiency has not been proved or disproved.

METHODS OF STUDY

The purpose of this project has been to determine the emergence and survival of grass seeds pelleted with various coating materials when planted under three methods of land treatment and two types of planting during two different seasons. This study was begun September, 1949, and completed March, 1951.

LOCATION AND DESCRIPTION OF SITE

The experimental plot, representative of thousands of acres of Intermountain sagebrush foothill ranges, is located at the base of the Bear River Mountain Range on the east side of Cache Valley, Utah, approximately one mile south of the mouth of Millville Canyon. The area is situated on a pre-Lake Bonneville alluvial fan between the Provo and Bonneville shore levels at an elevation of approximately 5,000 feet. The entire plot has a westerly exposure and dips slightly to the north (figure 1).

Vegetation: The area has been classified by Stoddart (21) as an Agropyron Consociation of the Palouse Prairie, big sagebrush (*Artemisia tridentata*) undoubtedly being a climax constituent. Although bluebunch wheatgrass (*Agropyron spicatum*) was originally understory to the sagebrush, overgrazing has eliminated it and left sagebrush as the dominant. The misuse of these lands has encouraged the development of cheatgrass (*Bromus tectorum*) and Sandberg bluegrass (*Poa secunda*) as understory species. The sagebrush has an estimated density of 20 percent, while the understory cover, cheatgrass and Sandberg bluegrass, has 30 and 10 percent densities respectively. Associated with these three species, but making up less than 5 percent of the vegetation

Figure 1. A typical sagebrush foothill range representative of the area on which this pellet seeding study was conducted

cover are yarrow (Achillea lanulosa), ivory-seeded borage (Lithospermum ruderale), snakeweed (Gutierrezia sarothrae), and tragopogon (Tragopogon spp.). Although not found in the plots, Utah Juniper (Juniperus utahensis) is scattered sparsely throughout the foothill area.

Soil: The soil is of limestone origin and is classified by Nelson and Eckmann (14) as a Millville Gravelly Loam. The top 10 to 18 inches consist of a grayish-brown to light brown friable, granular loam with various quantities of gravel. The subsoil which extends to a depth of 6 feet or more, is a light grayish-brown to light yellowish-gray calcareous gravelly loam to gravelly sand. The area is well-drained and free from alkali, and its position on the mountain slopes is high enough to give it some protection from late spring frosts. A mechanical analysis of the soil is shown in table 1. This sample contained more than .5 percent calcium carbonate.

Climate: The mean annual precipitation at Logan, over a period of 45 years, 1898-1943, was 16.55 inches. Seasonally, 34.32 percent of the precipitation fell in the spring, 13.47 percent in the summer, 25.32 percent in the fall, and 36.89 percent in the winter. The total amount received during the growing season, April 1 to October 1, was 43.5 percent (22).

The average annual precipitation for 1949-50 was 20.96 inches of which 32.53 percent fell in the spring, 8.84 percent in the summer, 28.0 percent in the fall, and 30.63 percent in the winter. The amount received during the 1950 growing season, April 1 to October 1, was 39.8 percent of the annual total (table 2).

Table 1. Textural classification of experimental soil as obtained by mechanical analysis
Data from Nelson and Eckmann (14)

Description	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
	(percent)	(percent)	(percent)	(percent)	(percent)	(percent)	(percent)
Top soil (depth 10 to 18")	4.4	3.7	2.5	5.3	20.2	48.9	15.2
Subsoil (depth 6')	5.9	8.4	6.6	14.0	21.4	31.4	12.7

Table 2. Monthly precipitation for water year of 1949-50 at Logan as compared to average (1898-1943)[1/]

Month	1949-50[2/]	1898-1943[3/]
	(inches)	(inches)
October	2.97	1.76
November	1.23	1.26
December	2.36	1.27
January	3.30	1.62
February	.76	1.56
March	2.01	1.88
April	1.63	1.92
May	3.18	1.88
June	.77	.89
July	.82	.62
August	.26	.72
September	1.67	1.17
Total	20.96	16.55

1/ Water year is designated as that period of time in which the soil mantle is first recharged in October of one year until its initial recharge in October of the subsequent year.

2/ Data from U. S. Weather Bureau (26).

3/ Data from Stoddart (22).

It can thus be seen that while the precipitation for the growing season of 1950 was only slightly below the mean, it was considerably less than average during the critical months of June and August. However, the total amount received for the water year 1949-50 was well above the 45-year average.

Although the average maximum and minimum temperatures throughout the growing season of 1950 were approximately 4 degrees below the 18-year average, 1931-49, they were generally favorable for normal growth (table 3).

EXPERIMENTAL DESIGN

The experiment was set up on a randomized split-plot design according to the methods prescribed by Cochran and Cox (6). Pellets were "drilled" or "broadcast" on untreated, plowed or burned areas in the fall of 1949 and the spring of 1950. Twelve plots were established to obtain all possible combinations of soil preparations, planting methods, and seasons of planting. Six of these plots were seeded in the fall and 6 in the spring. Each plot was divided into 110 square meter subplots to provide room for 2 replications of 49 types of prepared pellets and 1 check planting of bare seeds plus an unplanted strip of 10 square meters. Fifty seeds or individual pellets of each type were planted in each meter subplot. The unplanted strip was provided between each of the 12 major plots to divide treatments and planting methods (figures 2 and 3).

Species and Type of Pellet: Because of its perennial habit, high-yielding ability, drought resistance, and availability, crested wheatgrass was used in testing the efficiency of 49 different types of

Table 3. Average maximum and minimum temperatures for the growing season of 1950 at Logan as compared to average (1931-49) Data from U. S. Weather Bureau (26)

	1950		1931-49	
Month	Average maximum	Average minimum	Average maximum	Average minimum
	(degrees F.)	(degrees F.)	(degrees F.)	(degrees F.)
April	57.4	34.7	60.4	38.9
May	62.7	39.8	68.9	44.7
June	75.4	48.3	78.3	51.8
July	84.6	55.5	88.3	59.7
August	85.2	53.9	86.8	58.4
September	74.7	46.4	77.0	49.8

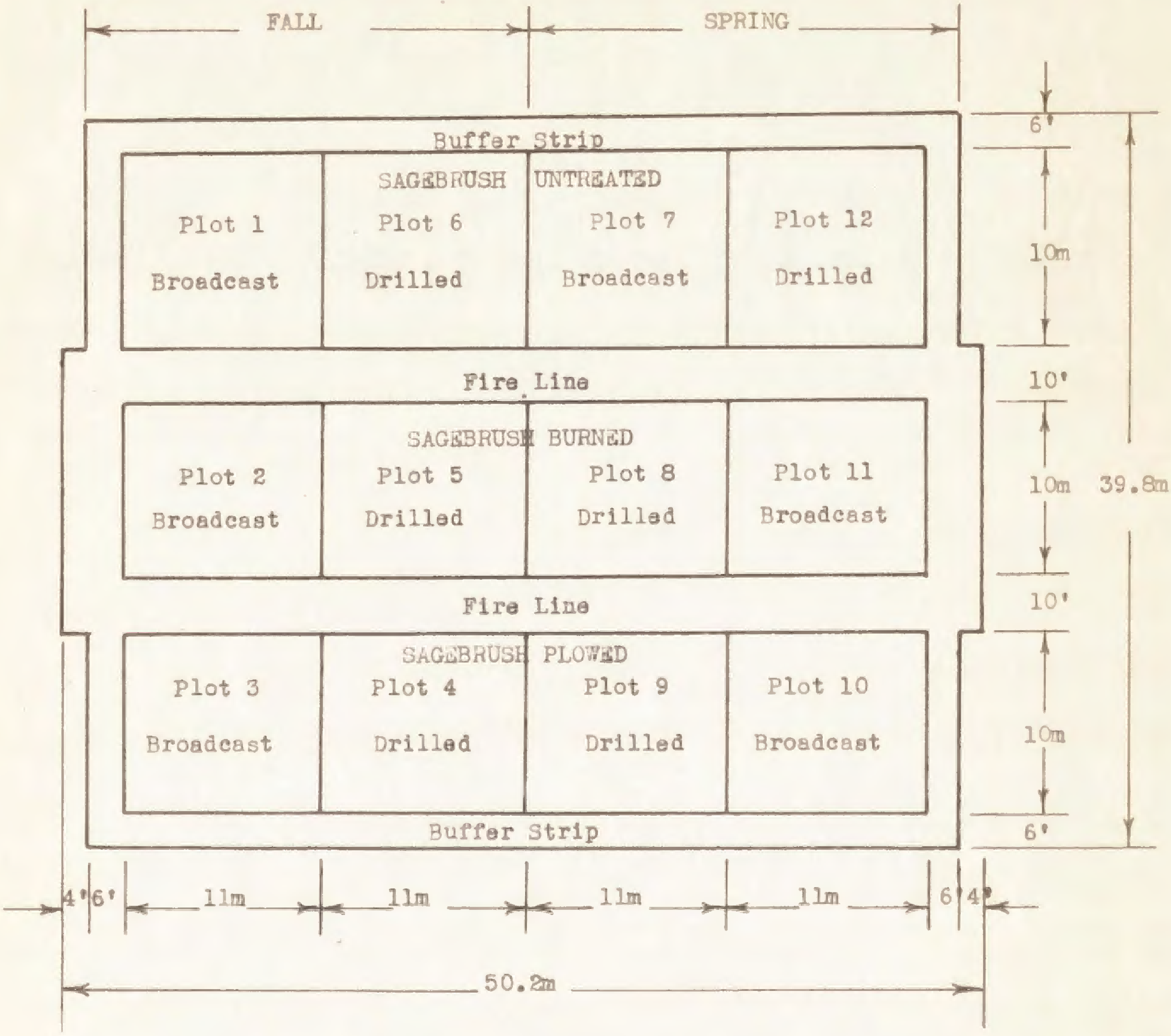

Figure 2. Diagram of field plan showing a total area of 1,933 square meters at a scale of one inch to 9.22 meters

11m

1m

WW	V	SEED	K	NN	Z	N	HH	EEE	RR	
YY	CCC	FF	GG	H	II	QQ	MM	UU	X	
Q	VV	KK	R	M	BB	CC	EE	ZZ	Y	Un
LL	S	OO	DD	P	JJ	PP	W	I	BBB	pla
U	J	O	T	L	DDD	SS	AAA	AA	XX	nted
S	KK	MM	LL	K	R	QQ	VV	I	OO	St
EEE	X	UU	L	NN	WW	T	Q	DD	EE	rip
J	SS	BBB	AA	AAA	YY	Z	JJ	CC	XX	
RR	N	H	DDD	HH	SEED	W	ZZ	II	PP	
P	BB	M	CCC	FF	V	GG	Y	O	U	

1m

10m

Figure 3. Diagram of plot plan showing a total area of 110 square meters at a scale of one inch to 1.850 meters (For explanation of code see table 4.)

plastic pellets. The coating material, the purpose of the coating material, and the serial number of each type of pellet can be found in tables 4 and 5. These pellets are of the type devised and manufactured by Mr. Phelps Vogelsang of the Processed Seeds, Inc., Midland, Michigan.

Ground Preparation and Planting: Plowing of plots and fire lines was done September 15 and 16, 1949, using a moldboard plow. The fire lines were then hand-grubbed to insure complete removal of all vegetation. On September 17, 1949, the designated area was burned by means of a gasoline weed-burner.

Iron fence posts were used to designate the corners of each plots, and small surveying stakes were placed on the perimeter to indicate 1-meter distances. Prior to planting, opposite stakes were connected by taut cords in both directions, thus establishing a grid to insure accurate location for purposes of recording seedling emergence and survival.

Twenty-five pellets or seeds were sown in each of 2 equally-spaced rows within each square-meter subplot, totaling either 50 pellets or 50 seeds (figure 4). When the pellet or seed was to be drilled, a furrow was made approximately one-half inch deep with the aid of a small pick. Pellets or seeds were then sown along it and covered immediately by leveling the surface soil. Plots 1 to 5 were sown October 7, 8, and 9, 1949, and plot 6 on October 14, 1949. Plots 7 to 12 were sown on April 15, 1950.

OBSERVATIONS

Periodic observations of seedling emergence were made throughout the winter and spring of 1949-50, and emerged seedlings from both fall and spring plantings were counted from June 9 to June 15, 1950. From

Table 4. Composition of the plastic pellets used in the experiment[1/]

Code number	Coating material[2/]
655-H	100% Feldspar, 40 Mesh
I	100% Aplite, 80 Mesh
J	100% Filtercel
K	100% Celite 209
L	80% Celite 209, 20% Fly Ash
M	50% Celite 209, 50% Activated Clay
N	100% Activated Clay
O	75% Celite 209
P	65% Celite 209, 35% Feldspar 40
Q	50% Filtercel, 50% Activated Clay, Fly Ash Layer
R	65% Filtercel, 35% Aplite
S	70% Filtercel, 30% Feldspar 40
T	70% Filtercel, 30% Aplite
U	60% Filtercel, 40% Activated Clay
V	65% Filtercel, 35% Feldspar 40, 2% Super Phosphate
W	65% Filtercel, 35% Feldspar 40, 4% Super Phosphate
X	65% Filtercel, 35% Feldspar 40, 8% Super Phosphate
Y	65% Filtercel, 35% Feldspar 40, 12% Super Phosphate
Z	65% Filtercel, 35% Feldspar 40, 10% Asbestos
AA	65% Filtercel, 35% Feldspar 40, 20% Asbestos
BB	65% Filtercel, 35% Feldspar 40, 5% $AlSO_4$
CC	65% Filtercel, 35% Feldspar 40, 10% $AlSO_4$
DD	65% Filtercel, 35% Feldspar 40, 15% $AlSO_4$
EE	50% Filtercel, 50% Feldspar
FF	50% Filtercel, 50% Feldspar, 2% Super Phosphate
GG	50% Filtercel, 50% Feldspar, 4% Super Phosphate
HH	50% Filtercel, 50% Feldspar, 8% Super Phosphate
II	50% Filtercel, 50% Feldspar, 12% Super Phosphate
JJ	50% Filtercel, 50% Feldspar, 10% Asbestos
KK	50% Filtercel, 50% Feldspar, 20% Asbestos
LL	50% Filtercel, 50% Feldspar, 2% $(NH_4)_2SO_4$
MM	50% Filtercel, 50% Feldspar, 4% $(NH_4)_2SO_4$
NN	50% Filtercel, 50% Feldspar, 8% $(NH_4)_2SO_4$
OO	50% Filtercel, 50% Feldspar, 200 PPM. Indol Butyric
PP	50% Filtercel, 50% Feldspar, 800 PPM. Blood, 100 PPM. Keto Succinic Acid
QQ	50% Filtercel, 50% Feldspar, 800 PPM. Fe Extract of Chlorophyll
RR	50% Filtercel, 50% Feldspar, 400 PPM. Inosital
SS	50% Filtercel, 50% Feldspar, 800 PPM. Praplant
UU	50% Filtercel, 50% Feldspar, 800 PPM. Phenolbarbital
VV	50% Filtercel, 50% Feldspar, 800 PPM. Naphthalene Acetic Acid
WW	50% Filtercel, 50% Feldspar, 1/4% Y. Cuprocide
XX	50% Filtercel, 50% Feldspar, 1/4% Chloranil
YY	50% Filtercel, 50% Feldspar, 1/4% Arasan, 281 Celite Top
ZZ	50% Filtercel, 50% Feldspar, 1/4% Semesan, 281 Celite Top
AAA	65% Filtercel, 35% Feldspar, 20% Powd. Methocel Layer
BBB	65% Filtercel, 35% Feldspar, 20% Solka Floc
CCC	60% Filtercel, 40% Activated Clay, 10% Casine
DDD	65% Filtercel, 35% Feldspar, 2% Super. 2% Cuprocide
EEE	65% Filtercel, 35% Feldspar, 4% Super. 1% Cuprocide 200 Inosital
Crested Wheatgrass Seed (Check)	

1/ Data from Vogelsang (27).

2/ For description and purpose of the coating material, see table 5.

Table 5. Purpose of the coating material used in making the plastic pellets
Data from Vogelsang (28)

Purpose	Coating material
Adherents	Activated clay (non-swelling absorbent clay)
	Aplite
	Asbestos
	Casine (dry casein powder)
	Celite (fine diatomaceous earth)
	Feldspar
	Filtercel
	Powdered methocel layer
	Solka floc (wood pulp fiber)
Binder	Methocel (methyl cellulose)
Control pH	Aluminum sulphate
Fertilizers	Ammonium sulphate
	Super phosphate
Fungicides	Arasan (tetramethyl thiuram disulphide)
	Chloranil (tetrachloro-p-benzoquinone)
	Semesan (ethyl mercury phosphate
	Y. Cuprocide (yellow copper oxide)
Increase porosity	Fly ash layer
Stimulants	Blood
	Indol-butyric (hormone)
	Inosital
	Iron extract of chlorophyll
	Keto succinic acid
	Naphthalene acetic acid
	Phenolbarbital
	Preplant

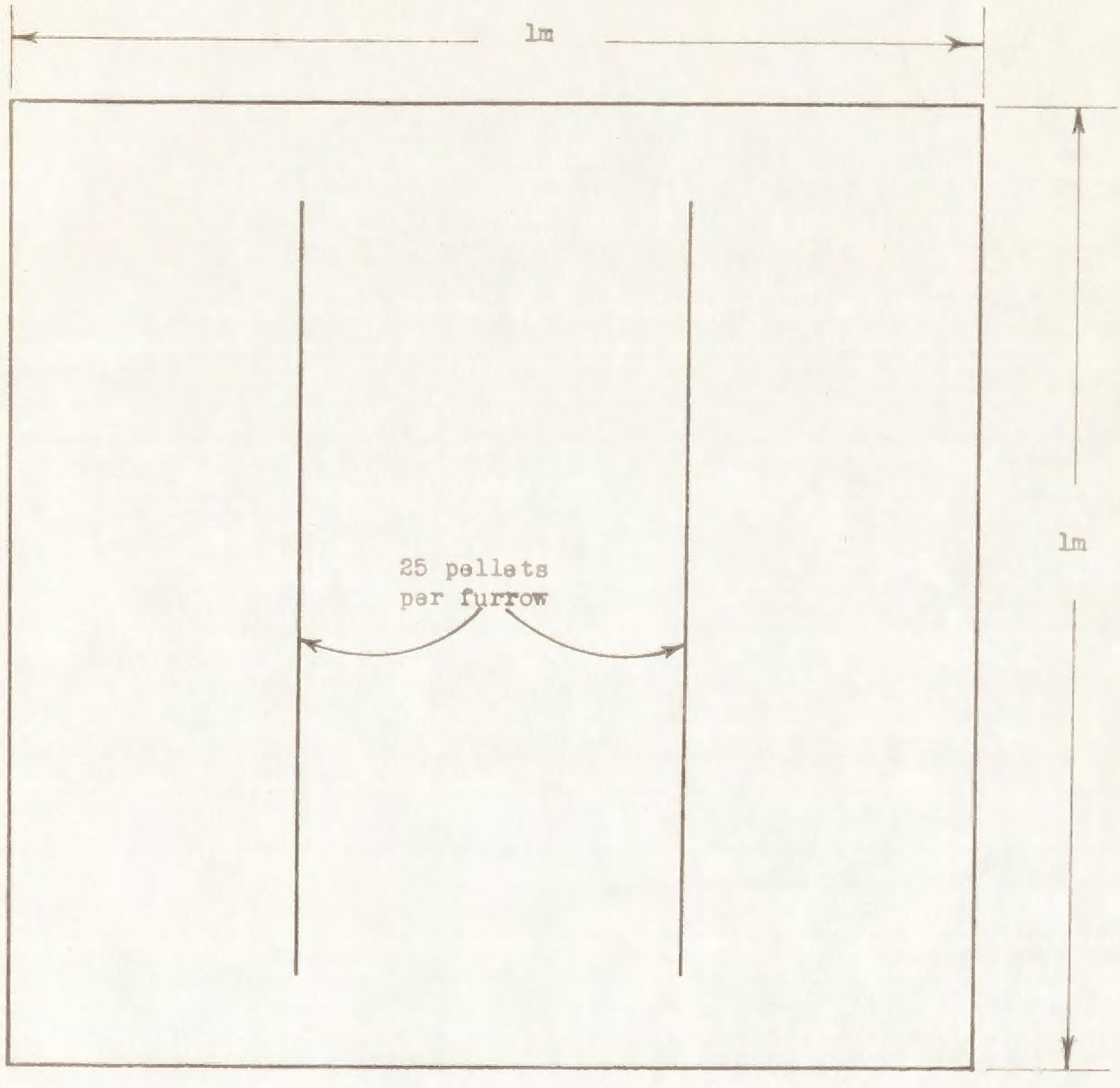

Figure 4. Diagram of subplot plan showing a total area of one square meter at a scale of one inch to .018 meters

September 24 to September 28, 1950, survival counts were made of both fall and spring plantings, and seedling survival was observed periodically until December 1, 1950.

In order to evaluate the effect of the time of storage on viability of the pellets and bare seeds, a germination test identical with that conducted by Vogelsang (27) in 1948 was made from January 15 to January 27, 1951, in the Utah State Agricultural College greenhouse. Plantings were made in 8-inch by 8-inch cardboard fruit baskets set in the ground and mudded in to eliminate air pockets and establish capillary contact with the surrounding soil. About one-half inch of the basket top was left above ground to minimize the danger of pellets washing from one basket to another. A planting diagram which provided room for 25 equally-spaced pellets was stamped lightly into each basket with a 7 1/2 inch by 7 1/2 inch board studded with nail heads. The depressions thus made in the soil surface not only provided for quick, uniform spacing, but for ease of checking pellet germination. Four replications of the 25 pellet plantings provided a total planting of 100 pellets of each kind and 100 bare seeds.

ANALYSIS OF DATA

Percentages of seedling emergence and survival, based upon the numbers planted and an average of 1.2 seeds per pellet, were determined for each type of pellet, bare seed, season of planting, method of land treatment, and method of planting. Because of the low emergence, a technique based on chi-square, Snedecor (17), was used in place of an analysis of variance. Both seedling emergence and survival were analyzed by this method.

RESULTS AND DISCUSSION

SEEDLING EMERGENCE

As shown in tables 6 and 7, emergence counts revealed that spring seeding was superior to fall; drilling was more successful than broadcasting; burned plots were more productive than either plowed or untreated, the latter's being the poorest of the three; and bare seeds were as good, or better, than any pellet with the exception of pellet number 655-NN. In all cases, however, seedling emergence and survival were extremely low.

Season of Planting: Table 7 indicates that seedling emergence was approximately twice as high for spring planting as for fall. Additional observations showed that the majority of the pellets and seeds planted in the fall did not emerge until early the following spring, and gained an initial advantage in growth over the spring-planted seedlings by being in the ground when conditions first became favorable for germination and emergence. In experiments conducted with bare seeds on similar areas, other authors have concluded that spring planting was best if seeding was done early (8, 20, 23).

The decrease in viability of the pellets and seeds by lying in the ground over winter is a possible explanation for the lower emergence from the fall seeding. A similar conclusion was made by Frischknecht (10) as a result of experiments conducted with late-fall planting.

Method of Planting: The number of seedlings which emerged from pellets and seeds drilled into the soil was about 8 times that from surface planting (table 7). Other seeding experiments, conducted on

Table 6. Seedling emergence from various types of pellets compared to bare seed[1]

	Number emerged	Emergence	Chi-square[2]
		(percent)	
Pellets			
655-H	34	2.34	0.49
I	35	2.41	0.33
J	19	1.31	7.50**
K	25	1.72	3.80
L	42	2.90	0.04
M	36	2.48	0.21
N	33	2.28	0.78
O	48	3.31	0.73
P	17	1.17	9.26**
Q	37	2.55	0.12
R	32	2.20	0.89
S	53	3.65	1.82
T	46	3.17	0.42
U	26	1.79	2.96
V	24	1.65	4.00*
W	43	2.96	0.11
X	40	2.76	0.00
Y	32	2.20	0.89
Z	50	3.45	1.11
AA	45	3.10	0.29
BB	31	2.14	1.14
CC	38	2.62	0.05
DD	24	1.65	4.00*
EE	29	2.00	1.75
FF	54	3.72	2.08
GG	39	2.69	0.05
HH	47	3.24	0.01
II	54	3.72	2.08
JJ	39	2.69	0.05
KK	34	2.34	0.49
LL	52	3.58	1.56
MM	51	3.51	1.33
NN	63	4.34	5.14*
OO	43	2.96	0.11
PP	19	1.31	7.50**
QQ	11	0.76	16.50**
RR	29	2.00	1.75
SS	31	2.14	1.14
UU	11	0.76	16.50**
VV	32	2.20	0.89
WW	17	1.17	9.26**
XX	22	1.52	5.22*
YY	36	2.48	0.21
ZZ	41	2.83	0.01
AAA	32	2.20	0.89
BBB	36	2.48	0.21
CCC	37	2.55	0.12
DDD	29	2.00	1.75
EEE	23	1.58	4.58*
Bare seed	40	3.32	—
Total	1,762	2.46	122.12**

[1]Number of seeds planted computed on the basis of an average of 1.2 seeds per pellet. Percent emergence based on total number of seeds planted.
[2]Bare seed was used as the base or expected value for determining chi-square.

*Results deviating significantly from those of bare seed.
**Results deviating highly significantly from those of bare seed.

Table 7. Comparison of seedling emergence from pellets and seeds planted under various conditions, and a statistical analysis of data[1]

Treatment	Number emerged	Emergence	Mean	Sum of squares	Chi-square
		(percent)			
Season of planting					
Fall	657	1.83			
Spring	1,105	3.08			
Total	1,762	2.46	881	100,352	114**
Method of planting					
Drilled	1,569	4.37			
Broadcast	193	0.54			
Total	1,762	2.46	881	946,688	1,074**
Method of land treatment					
Burned	1,195	5.00			
Plowed	400	1.68			
Untreated	167	.70			
Total	1,762	2.46	587		
B. vs. P.			797.5	316,012.5	396**
B. vs. U.			681.0	528,392.0	775**
P. vs. U.			283.5	27,144.5	96**

[1] Number of seeds planted computed on the basis of an average of 1.2 seeds per pellet. Percent emergence based on total number of seeds planted.

**Significant at .01 level.

foothill ranges, showed a need for covering seeds to insure success (8, 20, 23).

Approximately 2 weeks after the fall planting had been completed, rains washed the material from a large number of the broadcast pellets and left the seeds exposed to drought and wind. One week later very few of these seeds could be found. Similar observations were made of the spring seeding. In comparing Adams', Vogelsang's, and Burgesser's pellets, Murphy (13) observed that all types of pellets disintegrated and exposed the seeds to drying and scattering when planted on the range.

Method of Land Treatment: It can be seen in table 7 that burning gave approximately 3 times greater emergence than plowing and 7 times greater emergence than from the untreated strip. A comparison of emergence between the plowed and untreated areas showed the former to be 2 1/2 times more effective.

Estimates indicated no reduction in density of sagebrush, cheatgrass, and Sandberg bluegrass on the untreated area during the progress of the experiment. Conversely, burning effected a 100 percent kill of sagebrush, but no reduction in the densities of the two grasses. Although plowing did not reduce the density of cheatgrass, it did eradicate 70 percent of the sagebrush and 50 percent of the Sandberg bluegrass.

It has been pointed out by other experimenters that successful burning of cheatgrass must be accomplished before the seed has shattered out (18,20). In this study, burning failed to prove effective in destroying the cheatgrass because the seed had already matured and

been dispersed. Burning did not reduce the density of Sandberg bluegrass because its perennial parts are below the ground.

The ineffectiveness of plowing in lowering cheatgrass competition can also be attributed to the shattering out of the seed previous to cultivation. However, the shallow plowing effected a marked decrease in the density of Sandberg bluegrass by exposing the perennial parts to desiccation.

Type of Pellet: Of the 49 types of plastic pellets tested, the following gave significantly poorer emergence than bare seeds: 655-J, P, V, DD, PP, QQ, UU, WW, XX, and EEE. Seedling emergence from all other pellets did not vary significantly from that of bare seeds with the exception of 655-NN. This pellet gave 1 1/2 times greater emergence than bare seeds (table 6). Surprisingly, greenhouse tests conducted by Vogelsang showed germination of 655-NN to be the lowest of any of the pellets tested (table 8).

Vogelsang (27) concluded from his experiments that pellets 655-W, X, GG, and HH, containing a filtercel and feldspar base and 4 to 8 percent super phosphate, gave the best germination. However, the present study conducted on the sagebrush area showed that these same pellets gave no better emergence than bare seeds.

It should also be noted that of the 10 pellets which gave significantly lower emergence, 5 contained chemicals classified as stimulants or fungicides by Vogelsang, and equal proportions of filtercel and feldspar (tables 4 and 5). Pellet 655-NN also contained filtercel and feldspar in equal amounts, but a fertilizer, 8 percent ammonium sulfate was added rather than a stimulant or a fungicide (tables 4 and 5).

Table 8. Germination tests conducted at Utah State Agricultural College greenhouse and comparable tests conducted by Vogelsang

Pellet type	Germination (percent): Results of this study, January, 1951 — 5th day	7th day	14th day	Vogelsang's results[1/], September, 1948 — 5th day	7th day
655-H	12	41	59	66	82
I	18	28	43	68	83
J	14	34	56	64	72
K	17	46	69	68	68
L	15	32	68	58	58
M	20	36	58	70	80
N	4	13	32	62	70
O	10	29	50	64	74
P	11	31	47	74	92
Q	4	24	42	74	80
R	12	38	61	42	78
S	19	39	55	58	74
T	20	34	54	65	78
U	7	16	39	70	74
V	13	24	43	56	68
W	18	33	58	56	67
X	12	29	48	60	68
Y	9	18	33	72	76
Z	8	24	45	68	80
AA	16	41	58	80	80
BB	24	48	70	68	68
CC	5	20	32	68	70
DD	15	36	41	60	60
EE	4	14	26	76	80
FF	3	25	45	60	64
GG	7	24	40	18	76
HH	6	17	33	76	84
II	2	15	38	60	60
JJ	7	22	42	68	68
KK	6	22	59	64	64
LL	13	28	41	60	60
MM	3	21	38	64	68
NN	11	21	46	56	56
OO	11	21	51	68	72
PP	4	20	35	88	92
QQ	13	35	58	68	68
RR	16	29	51	64	68
SS	6	25	32	64	70
UU	8	19	38	68	64
VV	4	14	39	76	84
WW	9	20	46	68	76
XX	8	24	41	76	76
YY	14	28	46	60	60
ZZ	10	23	41	66	72
AAA	25	38	59	76	84
BBB	5	24	45	60	88
CCC	7	20	45	76	76
DDD	1	15	38	64	72
EEE	6	16	43	52	72
Bare seed	46	63	86	40	44

1/ Data from Vogelsang (27).

An examination of the material contained in the pellets giving emergence comparable with bare seeds shows that many contain, along with the filtercel and feldspar base, either a stimulant, fungicide, or a fertilizer (tables 4, 5, and 6).

SEEDLING SURVIVAL

As seen in tables 9 and 10, seedling emergence was 4 1/2 times greater than survival.[1/] Survival was not consistently related to emergence, but varied between seasons of planting, methods of land treatment, and type of pellets used.

Fall planting resulted in higher survival percentages than spring; drilling was higher than broadcasting; plowed plots were more efficient than burned or untreated, no difference existing between the latter two; and bare seeds were as good as any pellet with the exception of 655-T, X, BB, FF, GG, II, JJ, MM, and OO.

Season of Planting: Seedling survival from plantings made in the fall totaled 394, while not one seedling was found from the spring seeding (table 10). This was a complete reversal of the results obtained from seedling emergence. The logical explanation of this reversal is that seeding was made too late in the spring because of inclement weather. Other experimenters recommend early spring seeding for maximum success (8, 20, 23).

Observations made in the early summer showed that the fall seedlings had developed a bunch habit and had an average basal area of approximately 2 square inches and a height of 6 to 7 inches. The

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[1/] Seedling survival was determined 6 months after spring planting and 1 year after fall planting.

Table 9. Seedling survival from various types of pellets compared to bare seed[1]

Treatment	Number survived	Survival: Percent of seeds planted	Survival: Percent of seedlings emerged	Chi-square[2]
Pellets				
655-H	0	0.00	0.00	4.00*
I	4	0.28	11.40	0.00
J	9	0.62	47.40	1.92
K	5	0.34	20.00	0.11
L	5	0.34	11.90	0.11
M	9	0.62	25.00	1.92
N	6	0.41	18.15	0.40
O	7	0.48	14.55	0.82
P	3	0.21	17.60	1.27
Q	6	0.41	16.20	0.40
R	5	0.34	15.60	0.11
S	10	0.69	18.85	2.57
T	18	1.24	39.10	8.90**
U	8	0.55	30.70	1.33
V	11	0.76	45.90	3.27
W	11	0.76	25.60	3.27
X	22	1.52	55.00	12.45**
Y	9	0.62	28.10	1.92
Z	4	0.28	8.00	0.00
AA	7	0.48	15.50	0.82
BB	15	1.03	48.40	6.36*
CC	11	0.76	29.00	3.27
DD	8	0.55	33.33	1.33
EE	9	0.62	31.00	1.92
FF	12	0.83	22.20	4.00*
GG	12	0.83	30.80	4.00*
HH	11	0.76	23.40	3.27
II	15	1.03	27.80	6.36*
JJ	12	0.83	30.80	4.00*
KK	10	0.69	29.40	2.57
LL	10	0.69	19.20	2.57
MM	12	0.83	23.50	4.00*
NN	9	0.62	14.25	1.92
OO	13	0.90	30.20	4.76*
PP	3	0.21	15.80	0.01
QQ	6	0.41	54.50	0.40
RR	6	0.41	12.06	0.40
SS	4	0.28	12.90	0.00
UU	3	0.21	27.30	0.01
VV	5	0.34	15.60	0.11
WW	5	0.34	29.40	0.11
XX	3	0.21	13.60	0.01
YY	0	0.00	0.00	4.00*
ZZ	7	0.48	17.05	0.82
AAA	9	0.62	28.05	1.92
BBB	10	0.69	27.80	2.57
CCC	5	0.34	13.50	0.11
DDD	6	0.41	20.65	0.40
EEE	0	0.00	0.00	4.00*
Bare seed	4	0.33	10.00	—
Total	394	0.55	22.35	113.53**

[1] Number of seeds planted computed on the basis of an average of 1.2 seeds per pellet. Seedling survival was determined 6 months after spring planting and 1 year after fall planting.

[2] Bare seed was used as the base or expected value for determining chi-square.

*Results deviating significantly from those of bare seed.

**Results deviating highly significantly from those of bare seed.

Table 10. Comparison of seedling survival from pellets and seeds planted under various conditions, and a statistical analysis of data[1]

Treatment	Number survived	Survival: Percent of seeds planted	Survival: Percent of seedlings emerged	Mean	Sum of squares	Chi-square
Season of planting						
Fall	394	1.10	60.00			
Spring	0	0.00	0.00			
Total	394	0.55	22.35	197	77,610	394**
Method of planting						
Drilled	391	1.09	24.95			
Broadcast	3	0.01	1.55			
Total	394	0.55	22.35	197	75,272	382**
Method of land treatment						
Burned	0	0.00	0.00			
Plowed	394	1.65	98.50			
Untreated	0	0.00	0.00			
Total	394	0.55	22.35	131.3		
B. vs. P.				197	77,610	394**
B. vs. U.				0	0	0
P. vs. U.				197	77,610	394**

[1] Number of seeds planted computed on the basis of an average of 1.2 seeds per pellet. Seedling survival was determined 6 months after spring planting and 1 year after fall planting.

**Significant at .01 level.

seedlings from spring planting were no more than 1 inch in height. The fall seedlings, being more firmly established, were more capable of withstanding desiccation during the hot summer months.

Method of Planting: The number of seedlings which survived from drilled pellets and seeds was about 130 times that from surface planting (table 10).

The low survival of the seedlings that emerged from broadcast seeding could be attributed to their inability to anchor themselves firmly. In addition to establishing only one or two roots in the ground, the majority of the seedlings were not attached to the soil surface at their root crown, but rather at a position along the roots one-half to 1 inch below the crown. Conversely, the seedlings emerging from drilled plantings were more firmly anchored as the root crowns were one-half inch below the soil surface. Because of the marked difference in root development, less water and nutrients were available to the plants from broadcast seedings than to those from drilled. Furthermore, there likely was a tendency toward desiccation of the crown and upper root of the surface-planted seedlings.

Method of Land Treatment: As noted in table 10, the surviving seedlings on the plowed area totaled 394. None survived on the burned and untreated strips.

The more complete reduction of perennial grass competition from plowing is a possible explanation for survival occurring only on the plowed area. Experiments conducted by investigators on the seeding of sagebrush and cheatgrass lands have shown that the success of seedling

survival is indirectly related to the amount of competition (4, 15, 18, 20, 23).

Type of Pellet: Counts from 49 types of plastic pellets showed that 655-T, X, BB, FF, GG, II, JJ, MM, and OO gave markedly better survival than bare seeds. The seedling survival from all other pellets was not significantly higher than from bare seeds (table 9).

Survival counts tended to substantiate Vogelsang's recommendations that the pellets containing equal proportions of filtercel and feldspar with 4 to 8 percent super phosphate would give the best results. Of the 9 pellets which gave better survival, 4 contained the filtercel-feldspar base and super phosphate. However, the strength of the super phosphate varied from 2 to 12 percent. As seen in table 4, pellets 655-NN, which gave higher emergence, and 655-BB, which gave higher survival than bare seeds, contain filtercel, feldspar, and ammonium sulfate, but the ratios of the fertilizer, as well as the adherents, vary. Although pellet 655-NN gave higher emergence, it gave no greater survival than bare seeds. The pellets evidencing better survival showed no higher emergence than bare seeds (table 9).

GREENHOUSE AND LABORATORY TESTS

The greenhouse tests conducted at Utah State Agricultural College gave lower pellet and higher bare seed germination than comparable experiments made by Vogelsang (table 8).

Because these tests were identical as to design, environmental conditions, and type of pellet, the only plausible explanation for differences would be a reduction in viability of the pelleted seed and an increase in viability of the unpelleted seed during storage.

Perhaps a chemical or physical reaction effected by pelleting increases the physiological activity of the seed so that it shortens markedly the period of viability.

From a limited sample composed of 150 unemerged pelleted seeds recovered from the spring planting at random on October 14, 1950, 12 percent had germinated and only 1 of the remaining seeds germinated when placed in a germinator. Thus a 2 1/2 percent field emergence, plus the 12 percent germination in the field that failed to emerge, and the .75 percent germination gave a theoretical 15.25 percent germination under field conditions. A comparison of the greenhouse germination tests and the theoretical field germination shows the former to be 34 percent greater than the latter. Similar tests conducted by Cook (7) have indicated a marked difference between controlled laboratory germination tests and field germination.

CONCLUSIONS

The data obtained in this study indicate that there is no justification for the use of plastic pellets in seeding sagebrush foothill ranges of the Intermountain Region, and that the publicity which these pellets have received is not warranted.

Plastic pellets do not provide adequate protection for the seeds planted on the surface of the ground to permit an increase in germination and growth. The pellets break down immediately when wetted and expose the seeds to drought, insects, and rodents. The seedlings from broadcasted pellets do not anchor themselves firmly, and thus are unable to obtain sufficient water and nutrients to insure survival. In addition, there likely was a tendency toward desiccation of the crown and upper root of the surface-planted seedlings.

Although pellets number 655-T, X, BB, FF, GG, II, JJ, MM, and OO gave significatly higher survival than bare seeds, it cannot be concluded definitely that these pellets will insure a better stand of grass. Such a conclusion is unjustified because survival percentages were too low to yield satisfactory data regarding ultimate grass establishment. Furthermore, the low emergence from these 9 types of pellets would prevent the establishment of an adequate stand of grass regardless of survival. However, it is recommended that further investigations be conducted to determine possible effects of pelleting on seedling survival percentages.

Under greenhouse conditions, bare seeds evidenced materially higher germination than any of the 49 types of plastic pellets.

Pelleting apparently reduced the viability of the seed during storage. Perhaps a chemical or physical reaction effected by pelleting increases the physiological activity of the seed so that it shortens markedly the period of viability.

SUMMARY

1. To determine the effects of pellet seeding in improving western range lands, a study was conducted from September, 1949, to March, 1951, on a sagebrush foothill range near Logan, Utah. Observations were made on seedling emergence and survival from 49 plastic-coated crested wheatgrass pellets and bare seeds. Pellets were drilled and broadcast on untreated, plowed, and burned areas in the fall of 1949 and the spring of 1950. The experiment involved a randomized split-plot design. Subsequent greenhouse and laboratory tests were conducted to evaluate better the results of this study.

2. The majority of the fall-planted seedlings did not emerge until early the following spring. The total emergence from fall planting was approximately one-half that from spring planting.

3. The number of seedlings which emerged from pellets and seeds drilled into the soil was about 8 times that from surface planting.

4. The area burned gave approximately 3 times greater emergence than the area plowed and 7 times greater emergence than the untreated strip.

5. An analysis of the emergence from 49 types of plastic pellets indicated that 10 types gave significantly lower emergence than bare seeds, and only 1 gave higher emergence. Seedling emergence from all other pellets did not vary significantly from that of bare seeds.

6. Seedling survival was not consistently related to emergence, but varied between seasons of planting, methods of land treatment, and type of pellets used.

7. Survival counts made September 24 to 28, 1950, on fall plantings showed 394 seedlings surviving while not one seedling from the spring seeding survived the dry summer.

8. The number of seedlings which survived from drilled pellets and seeds was nearly 130 times that from surface planting.

9. The surviving seedlings on the plowed area totaled 394, while none survived on the burned and untreated strips.

10. Counts from 49 types of chemical pellets showed that 9 types gave markedly better survival than bare seeds. The seedling survival from all other pellets was not significantly higher than from bare seeds.

11. From this study, it was concluded that seeding sagebrush foothill ranges of the Intermountain Region with plastic-coated pellets is not warranted. Pelleting does not provide adequate protection for the seeds planted on the surface of the ground to permit an increase in germination and growth. Under greenhouse conditions, bare seeds evidenced materially higher germination than any of the 49 types of plastic pellets. Apparently, the pellet coating effects a marked reduction in the viability of the seed during storage. Although 9 types of pellets gave significantly higher survival than bare seeds, the extremely low survival renders any conclusions regarding ultimate grass establishment questionable. In addition, the low emergence from pellets would prevent the establishment of an adequate stand of grass regardless of survival.

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