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THE EFFECT OF PELLETING ON THE
GERMINATION OF VEGETABLE SEEDS

Thesis for the Degree of M. S.
MICHIGAN STATE COLLEGE
William Carl McGuffey
1949

This is to certify that the

thesis entitled

The Effect of Pelletizing on the Germination
of Vegetable Seeds

presented by

William Earl McGuffey

has been accepted towards fulfillment
of the requirements for

M. S. degree in Horticulture



Major professor

Date March 11, 1949

THE EFFECT OF PELLETING ON THE
GERMINATION OF VEGETABLE SEEDS

By

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A THESIS

Submitted to the School of Graduate Studies of
Michigan State College of Agriculture and
Applied Science in partial fulfillment of
the requirements for the degree of

MASTER OF SCIENCE

Department of Horticulture

March 1949

ACKNOWLEDGMENTS

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The author wishes to express his most sincere appreciation to Doctor R. L. Carolus for his direction and planning of the experimental work, and criticisms in the preparation of this manuscript; to the Ferry Morse Seed Company, Detroit, Michigan, for its contribution of seed used in this problem; and to Doctor P. Vogelsang, of the Processed Seeds Inc., Midland, Michigan, for the time and materials consumed in processing the seed.

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THE EFFECT OF PELLETING ON THE GERMINATION OF VEGETABLE SEEDS

INTRODUCTION

Due to the high cost of production, many new techniques and practices are being developed to increase the efficiency in agricultural operations. The pelleting of seed offers a possibility of aiding not only in the mechanization of the planting operation, but also in insuring a more uniform stand of many vegetable crops. Precision planting of small seeds, which can eliminate the costly practice of thinning and blocking, is made possible by means of pelleting seed. The process of pelleting will be economically feasible if the operation does not adversely affect germination.

Observations to date have indicated that under certain conditions, the pelleting of seed has had a detrimental effect upon germination. However, in many cases, especially with sugar beets⁽⁴⁾, pelleting of seed has markedly improved stands, particularly under unfavorable environmental conditions. Because of the possible aid to crop production that might result from this technique, a careful study of the various aspects of the problem appears to be warranted.

REVIEW OF LITERATURE

The treatment of seed with chemicals to attain fungicidal protection has been practiced for some time, and occupies a useful place in our agricultural methods of today⁽⁶⁾. There has been considerable work by Newhall⁽⁹⁾, Nelson⁽⁸⁾, Walker⁽¹⁴⁾ and many others to prove its worth. The trend has been from liquid to dust treatment of seed. Nelson⁽⁸⁾ indicates that even though formaldehyde provides better control of onion smut, it is being replaced by fungicidal dusts because of their ease of handling. Vogelsang⁽¹³⁾ suggests that the effectiveness of dust and liquid treatments can be improved by pelleting, because through this process it is possible to use fungicides at 10 to 50 times the concentrations that can be made to adhere to the seed by conventional methods. Linn and Newhall⁽⁷⁾ dipped onion seed in a 5 per cent methocel solution which enabled them to stick on a weight of fungicide equal to the weight of the seed. This treatment produced a coated seed that was both smaller and cheaper than the conventional pellet. Their experiments indicated that this treatment gave better smut control than pelleted seed. Nelson⁽⁸⁾ experimented with Newhall's type of pellet, but was inclined to favor the control method of sowing fungicidal dust in conjunction with the seed in a 1:4 ratio. However, he mentioned the possibilities of disease control with pelleted seed,

and indicated that many growers were receptive to this new technique because of its labor saving potentialities.

The Farmers and Manufacturers Beet Sugar Association of Saginaw have been pioneers in the practical development of pelleted seed. A considerable acreage of pelleted sugar beet seed has been planted in the last two years with favorable results⁽⁴⁾. Pelletting segmented sugar beet seed, in one test, resulted in a 20 per cent increase in germination under dry soil conditions, but 65 per cent increase in germination under wet soil conditions. It was suggested that soil organisms were more active in the wet soil, and as a result of pelletting, more effective control was obtained.

Kotowski⁽⁵⁾ showed in his work that different kinds of vegetables have different temperatures for optimum germination. He observed that crops like cabbage, spinach, cauliflower, beet, carrot and parsley have a higher per cent germination at temperatures below 50° F., while pepper, cucumber, beans and melons give higher per cent germination at 70° to 86° F. The other crops that he tested fell between these two extremes in the temperature required for optimum germination. Furthermore, Kotowski showed that with most crops a high temperature is probably optimum for the speed of emergence, but not for the production of the largest number of seedlings.

Aeration of the soil has an important effect on germina-

tion, and is related to soil texture, water relationships in the soil, and the oxygen requirement for germination of the seeds of different kinds of plants. Shull⁽¹⁰⁾ demonstrated that seeds of higher plants vary widely in the amount of oxygen required for germination. Some species like *Alisma Plantago-aquatica* (water plantain), rice and others can germinate under water, where no free oxygen is available, while other plants like *Xanthium* seeds need large amounts of free oxygen to germinate. He concludes that the majority of plants fall somewhere between these two extremes given in oxygen requirements for germination. Shull⁽¹⁰⁾ also found that a rise in temperature lowers the oxygen minimum needed by *Xanthium* for germination, and suggests that it might be due to the increase of anaerobic respiration at higher temperatures.

The Mechanics of Pelletting

Pelleting* is the process by which a coat of inert pulverized chemicals is made to adhere to the seed by a water soluble plastic (methocellulose). These inert materials may be fly ash, feldspar, celite, bentonite clay, or vermiculite. Fungicides, slightly soluble fertilizers, and growth regulators can be added to the pellet to give protection and stimulation to the seed and

*Information obtained from personal interviews with Dr. Phelps Vogelsang of the Processed Seeds Inc., Midland, Michigan

seedling. It is feasible, if desirable, to add a fungicide at 10 to 50 times the concentration that can be made to adhere to the seed with a dry dust treatment. The operation is performed in a rotary pan similar to those used in the manufacture of pills and candies. Pelleting may increase the volume of the seed from one to twenty times, and the weight from five to twenty-five times, depending upon the size of the seed. Small seed like onion can be processed to form a spherical pellet, while large seeds as corn are treated to form a coat of materials that does not materially change their original shape. If large seeds were treated to form a spherical pellet, their volume and weight might be increased to a point where the process would be impractical.

STATEMENT OF THE PROBLEM

Pelleting vegetable seeds to facilitate precision planting will be an economically sound practice if the process does not have a detrimental influence on germination. This paper presents results of experiments conducted to determine the influence of the coating material on germination and rate of emergence under various conditions. The germination of pelleted and unpelleted seed of fifteen vegetable crops will be compared under varying environmental conditions. The influence of temperature, soil moisture, and soil type on the relative germination and emergence of pelleted seed will be determined.

This investigation should indicate some of the problems and difficulties that may be encountered in practical operations with coated seed. The conditions under which the process is least detrimental to germination, and the kind of seed that can be most successfully pelleted will be indicated. In addition, this work can serve as background for future study involving the incorporation of other chemicals with the coating materials.

METHODS AND MATERIALS

A factorial experiment was conducted in which the germination and rates of emergence of 15 kinds of vegetable seeds, both pelleted and unpelleted, were determined. The seed was furnished by the Ferry Morse Seed Company of Detroit, and the seed was pelleted by the Processed Seeds, Inc., of Midland, Michigan. All germinations were conducted on two soil types, each at two moistures, and at four temperatures, representing 960 determinations. The seeds of the following crops were used:

KIND	VARIETY
Broccoli	DeCicco
Cabbage	Golden Acre
Chinese Cabbage	Michihli
Carrot	Chantenay
Cauliflower	Snowball X
Dill	Mammoth
Kale	Dwarfed Blue Curled
Mustard	Southern Giant Curled
Onion	Brigham Yellow Globe
Radish	Scarlet Globe
Rutabaga	Amer. Purple Top
Spinach	Virginia Savoyed
Parsnip	Hollow Crown
Tomato	Rutgers
Turnip	Purple Top White Globe

The seed was germinated in wooden flats 15" x 21" x 4" in size. The soil in the flats was firmed with a marking board, and 25 seeds planted in each of 10 rows spaced at two inch intervals. The seed was then covered with a measured amount of soil and firmed again. Five vegetables were planted in each flat with the pelleted seed planted adjacent to the check seed. All plantings

were replicated.

The pelleting material was composed of 35 per cent fly ash and 65 per cent feldspar, with methocel used as a sticker to form the pellet. Probably a pellet consisting of these three inert materials does not have any chemical effect on the seed. The soils used were a sandy loam and a well decomposed muck.

The optimum water content of the soil was found by experimentation to be approximately 87 per cent of field capacity. The weight of the water necessary to saturate a given weight of soil was calculated, and this quantity was added to a flat to obtain 100 per cent water holding capacity, and 70 per cent of that quantity was added to secure the optimum moisture content. The moisture relationships are shown by the data below.

MUCK SOIL			MINERAL SOIL	
PERCENTAGE H ₂ O DRY WT.	149%		25%	
	OPTIMUM MOISTURE	HIGH MOISTURE	OPTIMUM MOISTURE	HIGH MOISTURE
Percentage H ₂ O after watering	210.8%	237.2%	41.9%	49.3%
Percentage of water holding capacity	88.9%	100.0%	85.0%	100.0%

The seeds were germinated in four walk-in type refrigerators, in which the temperatures were maintained at approximately 40°, 50°, 60° and 70° F. The flats were stacked in groups of

four, and the stacking sequence rotated from time to time.

The flats were left in the constant temperature rooms for 14 days, and then they were removed to room temperature and completed germination at approximately 70° F.

Observations of the progress in the germination of each lot were made daily, and any seedling that had completely emerged was pinched off and counted. To obtain a weighted average of the number of days to emergence, the number of seedling that emerged each day was multiplied by the number of days to emergence, and the sum of these products was divided by the total number of seedlings that emerged.

To determine the most suitable depth of planting and moisture content of the soil for optimum germination, a preliminary study was conducted on the influence of these factors on the germination of five vegetables. Seed was planted in replicated flats containing muck and mineral soil at four moisture levels, and its germination was determined. To attain the effect of different depths of planting, varying amounts of soil were used to cover the seed. The five vegetables used were Sweet Spanish onion, Rutgers tomato, Slo-bolt lettuce, Danish Ball Head cabbage, and Nantes carrot. The data are reported in Tables I and II.

The figures in Table I show that the highest average germination obtained was at the 3/8" depth on muck, and at the 1/4"

TABLE I

EFFECT OF PLANTING DEPTH ON PERCENTAGE EMERGENCE
OF PELLETED AND CHECK VEGETABLE SEED AT 70° F.

CROP	MUCK SOIL				MINERAL SOIL				AVG.
	1/8"	1/4"	3/8"	1/2"	1/8"	1/4"	3/8"	1/2"	
ONION (P)	92 *	94	88	72	72	78	68	84	81
ONION (C)	82	90	88	84	74	94	92	90	86
TOMATO (P)	86	100	88	92	96	92	90	88	90
TOMATO (C)	88	78	84	80	80	76	70	76	79
LETTUCE (P)	64	58	60	48	54	76	44	50	57
LETTUCE (C)	68	80	84	64	60	76	52	56	67
CABBAGE (P)	84	82	82	84	76	94	84	72	82
CABBAGE (C)	94	86	82	90	88	96	82	80	90
CARROT (P)	78	78	86	64	70	72	56	72	72
CARROT (C)	82	84	90	72	80	72	64	66	76
AVERAGE (P)	80	82	81	72	73	82	68	73	76
AVERAGE (C)	83	84	86	78	76	83	72	74	80

*Average of four observations

TABLE II

EFFECT OF SOIL MOISTURE ON PERCENTAGE EMERGENCE
 OF PELLETED AND CHECK VEGETABLE SEED AT 70° F.
 PERCENTAGE OF FIELD CAPACITY

CROP	70% F. C.	78% F. C.	87% F. C.	100% F. C.	AVERAGE
ONION (P)	66*	86	82	84	80
ONION (C)	82	88	86	92	87
TOMATO (P)	70	80	100	84	84
TOMATO (C)	82	74	100	78	84
LETTUCE (P)	36	56	56	64	53
LETTUCE (C)	74	68	76	78	74
CABBAGE (P)	62	90	94	72	80
CABBAGE (C)	76	82	100	96	89
CARROT (P)	58	64	80	80	71
CARROT (C)	66	82	86	90	81
AVERAGE (P)	58	75	82	77	73
AVERAGE (C)	76	79	90	87	81

*Average of four observations

depth on mineral soil.

The highest per cent germination was secured in the soil with a moisture content of 87 per cent of field capacity (Table II). The reduction in germination obtained at the two lower moisture levels differs between the pelleted and check seed. At the 70 per cent level, pelleting reduced germination 18 per cent, while at the 78 per cent level pelleting reduced germination only 4 per cent. The data in this test showed that at both low (70 per cent) or high (100 per cent) moisture levels, pelleting is relatively more harmful to germination than at the intermediate moisture contents.

EXPERIMENTAL RESULTS

The information obtained with respect to the per cent germination of each of the 960 lots was subjected to a statistical analysis⁽¹²⁾. The significant effects of the various factors, and the first and second order interactions, are expressed in the analysis of variance summary. The third and fourth order interactions were placed in the error term. Due to the large number of degrees of freedom involved, the error is quite small, and consequently all of the main factors are highly significant, and many of the interactions are worth studying. The data on germination and rate of emergence are arranged in Tables III to VIII to portray the significant relationships.

Based on an average of all crops and all factors, pelleting reduced germination 15 per cent (Table III). Pelleting significantly reduced the germination of all crops except carrot, cauliflower and turnip. The figures in Table IV show that on an average of all conditions, pelleting delayed emergence by 1.2 days. However, with cauliflower and turnip, pelleting did not significantly lower germination, nor materially prolong the rate of emergence. With pelleted kale, mustard, onion, parsnip and tomato seed, a reduction in the per cent germination can be related to a pronounced increase in the time to emergence as compared to unpelleted seed. This relationship is easily observed graphically in Fig. 1.

PERCENT GERMINATION

ANALYSIS OF VARIANCE SUMMARY

SOURCE OF VARIANCE	D.F.	SUMS OF SQUARES	MEAN SQUARE	F VALUE
Replications	1	1	1.00	
Crops (C)	14	8,201	585.78**	65.09
Pellet Treatments (P)	1	3,264	3,264.00**	362.67
Soils (S)	1	499	499.00**	55.44
Moisture (M)	1	511	511.00**	56.78
Temperature (T)	3	314	104.47**	11.61
CxP	14	1,453	103.78**	11.53
CxS	14	825	58.93**	6.55
CxM	14	250	17.86*	1.98
CxT	42	1,874	44.61**	4.96
PxS	1	27	27.00	3.00
PxM	1	98	98.00**	10.89
PxT	3	46	15.33	1.70
SxM	1	10	10.00	1.11
SxT	3	80	26.67*	2.96
MxT	3	64	21.33	2.37
CxPxS	14	219	15.64*	1.74
CxPxM	14	213	15.21	1.69
CxPxT	42	823	19.60**	2.18
PxSxM	1	4	4.00	0.44
PxSxT	3	13	4.33	0.48
SxMxT	3	47	15.67	1.74
CxSxM	14	228	16.28*	1.81
CxSxT	42	344	8.19	0.91
CxMxT	42	515	12.26*	1.36
PxMxT	3	70	23.33	2.59
Error	644	5,975	9.0	
Total	959	25,968		

Snedecor's t Value		1%	5%
Least Difference for Sig:		2.586	1.960
Averages of	8	15.5	11.8
" "	16	10.9	8.3
" "	32	7.7	5.9
" "	64	5.5	4.2
" "	120	4.0	3.1
" "	240	2.8	2.1
" "	480	2.0	1.5

The average effect of temperature on the per cent germination and rate of emergence of pelleted seed is shown in Fig. 2 and Tables III and IV. The highest germination for both pellet and check seed was obtained at 50° F., and the most rapid rate of emergence was at 70° F. The relative (P/C) decrease in both germination and rate of emergence was more pronounced at the higher temperatures.

Table V and Fig. 3 express the relative effects of temperature on germination of pelleted and check seed. Small relative germination figures indicate serious harmful effect from pelleting; however, a large relative rate of emergence figure indicates a pronounced detrimental effect from pelleting. Pelleting had the effect of reducing relative germination and increasing the relative time to emergence at the high temperatures, while increasing the relative germination and reducing the relative time to emergence at low temperatures (Table V).

Table V indicates that with spinach, rutabaga, kale, cabbage and broccoli, the relative germination of pelleted seed decreased as the temperature increased; on the other hand, the relative germination of carrot, tomato and turnip increased with an increase in temperature. The relative rate of emergence of most crops, with the exception of spinach, was reduced more at the high temperatures than at the low temperatures. Pelleting reduced the relative germination of spinach and kale about

TABLE III
THE EFFECT OF TEMPERATURE AND PELLETING UPON
THE PERCENTAGE GERMINATION OF 15 VEGETABLE CROPS

CROP	70°		60°		50°		40°		P AVG. ALL TEMPS.	C AVG.
	P	C AVG.	P	C AVG.	P	C AVG.	P	C AVG.		
Broccoli	65.5*	90.0	77.8	88.5	84.2	94.0	86.2	84.5	77.1***	90.0
Cabbage	40.5	64.0	52.2	68.5	56.2	61.0	73.5	67.0	53.1	74.2
Ch. "	50.0	85.5	67.8	87.0	75.8	59.5	94.5	85.5	64.9	90.9
Carrot	84.5	83.0	83.8	81.0	80.5	92.0	87.5	88.5	83.8	84.8
Caulifl.	81.5	84.0	82.8	79.0	77.0	88.5	91.5	90.0	84.9	86.2
Dill	67.5	69.5	68.5	78.0	79.5	75.0	75.5	71.0	68.5	74.2
Kale	28.0	59.5	43.8	41.5	56.5	45.0	68.0	47.0	40.5	61.5
Mustard	78.5	85.5	82.0	68.5	77.2	84.5	85.0	84.8	75.5	84.9
Onion	68.5	85.0	76.8	69.0	80.0	75.0	87.0	81.0	68.6	88.5
Radish	69.5	98.0	83.8	76.5	85.8	83.0	97.5	90.2	76.2	95.6
Rutabaga	68.5	92.5	80.5	72.5	78.8	75.5	88.0	81.8	73.8	87.9
Spinach	19.5	58.5	39.0	31.5	45.2	51.5	64.5	58.0	40.1	61.9
Parsnip	50.0	87.0	68.5	54.5	69.2	45.0	88.5	66.8	46.9	83.4
Tomato	87.5	83.5	85.5	71.5	74.2	58.0	74.0	66.0	67.2	76.1
Turnip	81.0	78.5	79.8	90.0	91.8	92.0	91.5	91.8	87.4	89.5
AVERAGE	62.7**	80.3	71.5	66.8	74.1	70.9	84.7	77.8	67.2	82.0

* Average of 8 values

** " " 120 "

*** " " 32 "

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TABLE IV
AVERAGE DAYS TO EMERGENCE OF
PELLETED AND UNPELLETED VEGETABLE SEED

CROP	70°		60°		50°		40°		ALL TEMPERATURES		
	P	C	P	C	P	C	P	C	P	C	AVG.
Broccoli	3.69	2.62	5.02	4.42	7.26	6.49	14.84	14.80	7.70	7.08	7.39
Cabbage	5.89	4.27	7.33	6.62	10.08	8.39	16.00	15.76	9.82	8.76	9.29
Ch. "	3.57	2.31	5.34	4.31	6.97	5.70	15.66	14.52	7.88	6.71	7.30
Carrot	10.26	8.28	13.24	10.78	16.06	15.23	20.56	20.17	15.03	13.62	14.32
Caulifl.	7.38	6.18	7.48	6.30	12.91	11.99	24.24	23.39	13.00	11.96	12.48
Dill	9.72	6.79	13.75	11.43	18.94	17.24	21.84	21.20	16.06	14.16	15.11
Kale	6.46	4.51	8.14	7.14	12.74	11.05	18.45	17.78	11.45	10.12	10.78
Mustard	17.90	16.11	20.33	18.31	19.09	17.88	20.81	20.01	19.53	18.08	18.81
Onion	11.26	7.60	15.41	13.64	19.12	13.26	22.04	20.88	16.96	15.10	16.03
Parsnip	16.53	13.96	21.88	17.86	23.76	21.12	27.32	25.48	22.37	19.48	20.92
Radish	4.72	3.15	6.16	5.04	7.95	6.69	15.95	15.18	8.70	7.52	8.11
Rutabaga	5.76	4.47	7.75	6.95	12.28	9.90	17.64	17.40	10.86	9.68	10.27
Spinach	5.04	5.79	8.40	8.49	11.32	10.59	18.50	18.54	10.82	10.85	10.84
Tomato	8.81	6.82	12.51	9.76	17.73	16.42	22.86	20.89	15.48	13.47	14.48
Turnip	4.65	3.74	7.50	7.88	9.59	9.53	16.45	16.71	9.55	9.48	9.52
AVERAGE	8.11	6.44	10.68	9.23	13.72	12.44	19.54	18.85	13.03	11.72	12.38

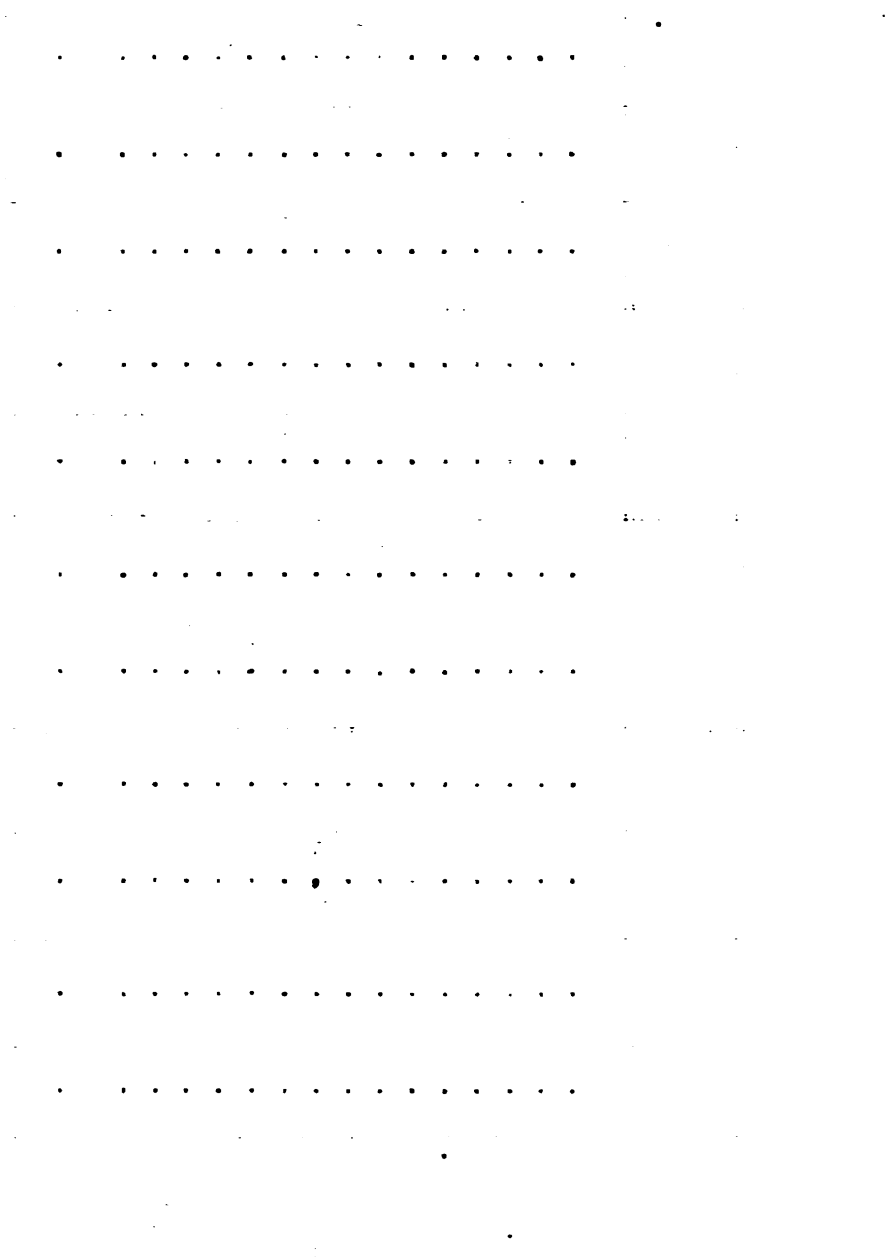


FIG. 1. THE INFLUENCE OF PELLETING ON GERMINATION AND RATE OF EMERGENCE

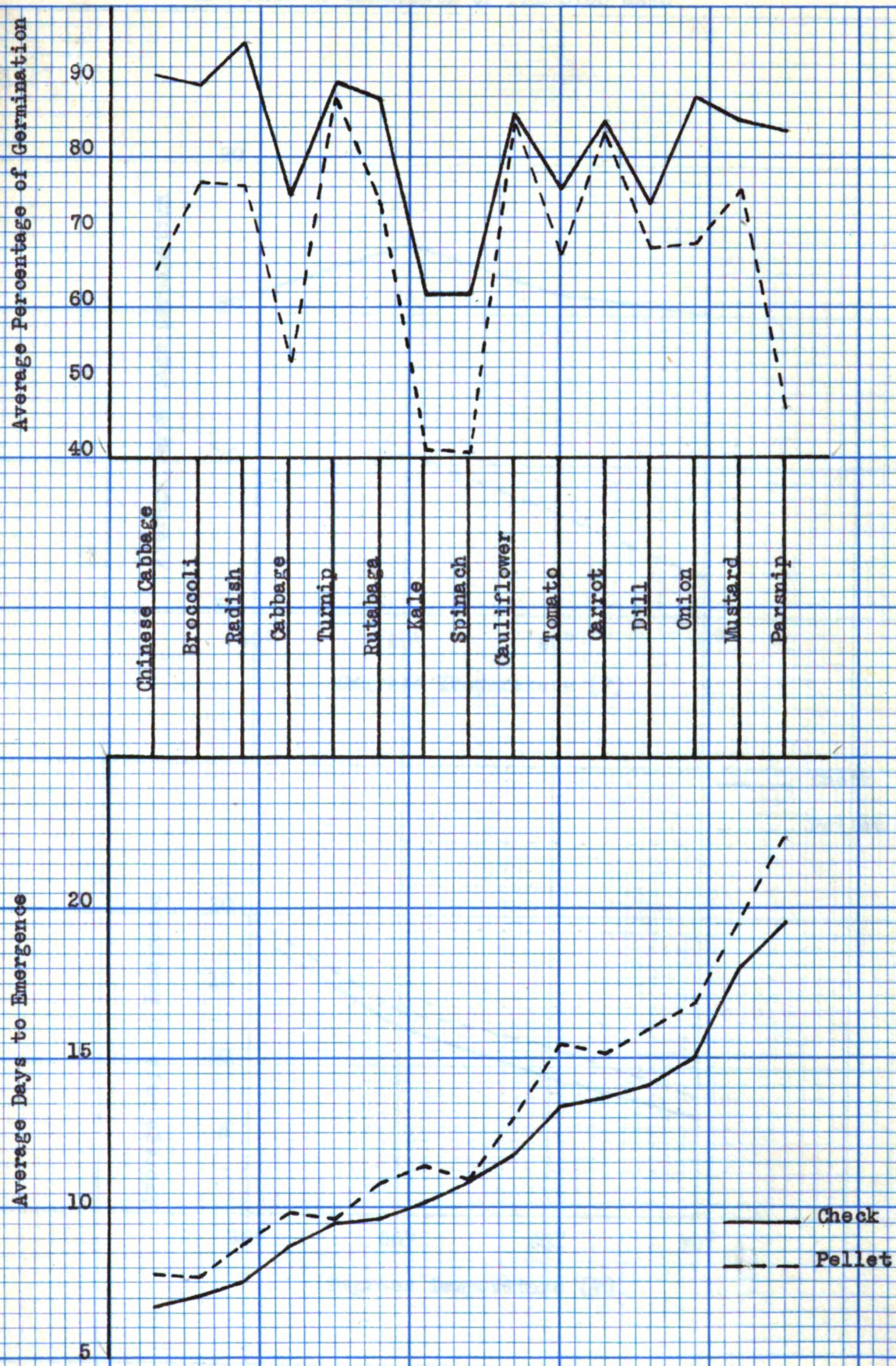


FIG. 2. THE INFLUENCE OF TEMPERATURE ON GERMINATION
AND RATE OF EMERGENCE OF PELLETED SEED

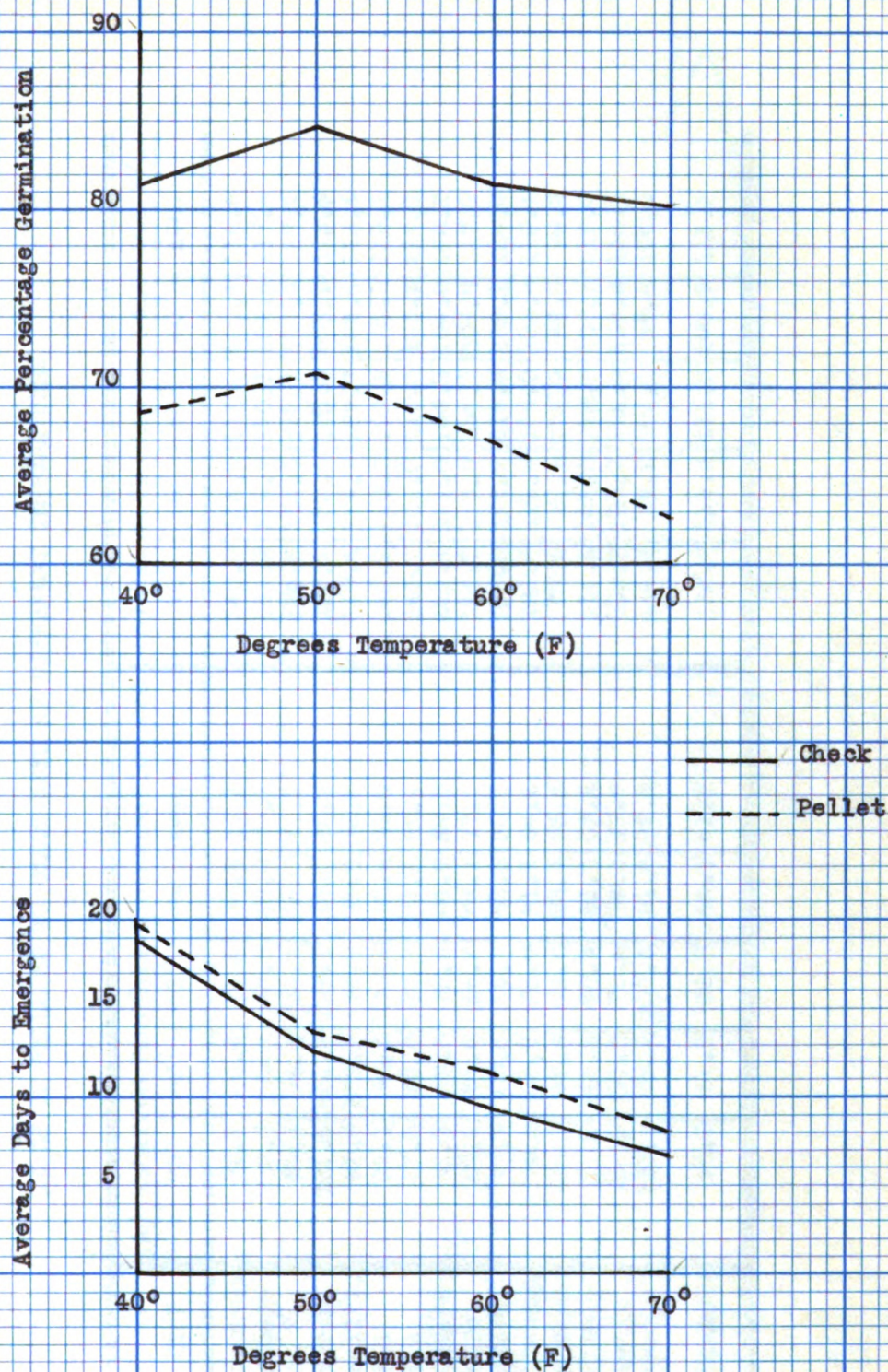
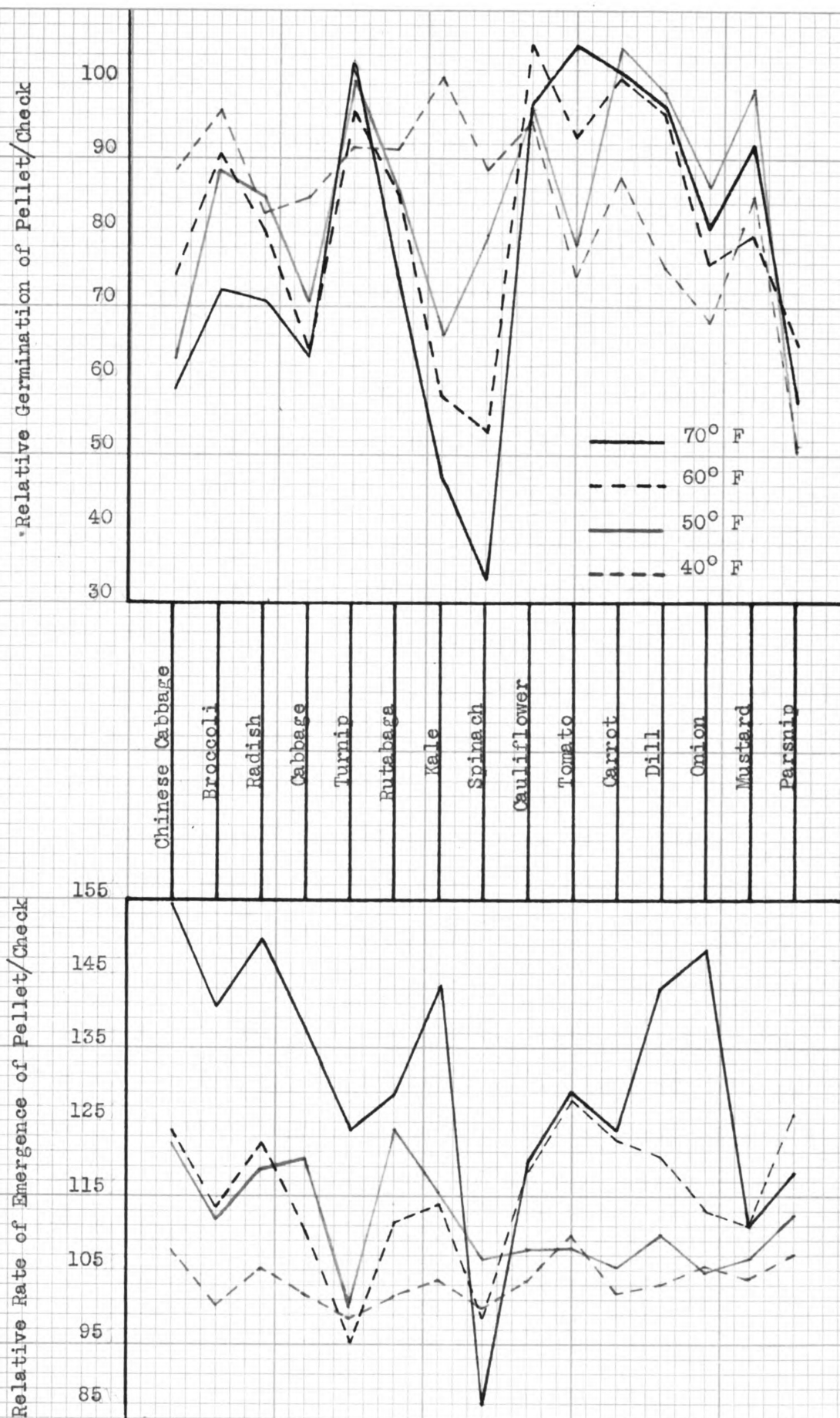


TABLE V
THE RELATIVE PERCENTAGE GERMINATION AND RATE OF EMER-
GENCE OF PELLETED TO CHECK SEED AT DIFFERENT TEMPERATURES

CROP	(A) RELATIVE PERCENTAGE GERMINATION P/C					(B) RELATIVE RATE OF EMERGENCE P/C				
	70°	60°	50°	40°	AVG.	70°	60°	50°	40°	AVG.
Broccoli	72.8	90.4	88.5	96.6	87.1	140.8	113.6	111.9	100.3	116.6
Cabbage	63.3	64.2	70.9	84.8	70.8	137.9	110.7	120.1	101.5	117.6
Ch. "	58.5	74.1	63.0	88.6	71.1	154.5	124.0	122.3	107.9	127.2
Carrot	101.8	101.2	105.1	87.6	98.9	123.9	122.8	105.4	101.9	113.5
Caulifl.	97.0	105.3	96.7	95.2	98.6	119.4	118.7	107.7	103.6	112.4
Dill	97.1	96.3	99.3	75.4	92.0	143.2	120.3	109.9	103.0	119.1
Kale	47.0	58.0	66.2	101.1	68.1	143.2	114.0	115.3	103.8	119.1
Mustard	91.8	79.6	99.4	84.9	88.9	111.1	111.0	106.8	104.0	108.2
Onion	80.6	75.8	86.2	68.1	77.7	148.2	113.0	104.7	105.6	117.9
Radish	70.9	80.5	85.1	82.6	80.0	149.8	122.2	118.8	105.1	124.0
Rutabaga	74.1	85.3	85.8	91.2	84.2	128.9	111.5	124.0	101.4	116.4
Spinach	33.3	53.4	79.8	88.5	63.8	87.0	98.9	106.9	99.8	98.2
Parsnip	57.5	64.9	50.8	51.4	56.2	118.4	126.0	112.5	107.2	116.0
Tomato	104.8	92.8	78.4	74.3	87.6	129.2	128.2	108.0	109.4	118.7
Turnip	103.2	96.2	100.5	91.5	97.8	124.3	95.2	100.1	98.4	104.5
AVERAGE	76.9	81.2	83.7	84.1	81.5	130.7	115.3	111.6	103.5	115.3

GERMINATION AND RATE OF EMERGENCE OF PELLETTED SEED



54 per cent more at 70° F. than at 40° F. The germination of parsnip was reduced by pelleting about 45 per cent at all temperatures, while the germination of cauliflower and turnip was reduced only 3 per cent based on the averages of all temperatures.

Table VI (A) shows that the relative germination of all crops with the exception of onion, radish, spinach, tomato and turnip was lower on mineral than on muck soil. Relative to the check, the pelleting of cabbage, cauliflower, dill, mustard, broccoli, Chinese cabbage and parsnip resulted in a higher per cent germination on muck than on mineral soil. These relative correlations can be graphically interpreted in Fig. 4. However, only with cauliflower, mustard, onion, parsnip and turnip did the pelleting process result in a pronounced higher relative time to emergence on muck than on mineral soil (Table VII).

Field capacity in this paper is considered synonymous with water holding capacity of a soil. Table VI (B) indicates that the highest per cent germination was obtained at the 87 per cent level, and only with cauliflower, tomato and parsnip did the pellet give a higher germination at 100 per cent field capacity. However, the germination of check seed shows small differences due to temperature, soil and moisture content of the soil as compared to the pellet.

Data in Table VIII shows that on an average of the 15

TABLE VI

THE PERCENTAGE GERMINATION OF PELLETTED VEGETABLE SEED ON

(A) TWO SOIL TYPES, AND (B) AT TWO SOIL MOISTURE CONTENTS

CROP	(A) SOIL TYPE						(B) PERCENTAGE OF WATER HOLDING CAPACITY					
	MINERAL			MUCK			RATIO P/C			87%		
	C		AVG.	C		AVG.	MIN'L.		MUCK	P		AVG.
	P	C	AVG.	P	C	AVG.	P	C	AVG.	P	C	AVG.
Broccoli	71.2*	87.8	79.5	83.0	92.2	87.6	81.1	90.0	84.5*	91.0	87.8	89.0
Cabbage	43.8	67.2	55.5	62.5	81.5	72.0	65.2	76.7	59.2	74.0	66.6	74.8
Ch. "	58.5	92.0	75.2	71.2	89.8	80.5	63.6	79.3	72.0	91.0	81.5	90.8
Carrot	81.2	87.2	84.2	86.2	82.2	84.2	93.1	104.9	84.2	83.5	83.9	86.0
Caulifl.	77.8	82.0	80.4	91.0	90.5	90.8	94.9	100.6	82.8	89.2	86.0	87.0
Dill	60.0	69.8	64.9	77.0	78.8	77.9	86.0	97.7	72.8	73.5	73.1	75.0
Kale	39.5	61.8	50.6	41.5	61.2	51.4	63.9	67.8	47.5	68.0	57.8	55.0
Mustard	68.8	78.5	73.6	82.2	91.2	86.8	87.6	90.1	81.2	86.0	83.6	83.8
Onion	68.0	83.5	75.8	69.2	93.5	81.4	81.4	74.0	72.5	90.5	81.5	86.5
Radish	77.8	94.0	85.9	74.8	97.2	86.0	82.7	77.0	81.8	96.2	89.0	95.0
Rutabaga	71.2	90.2	80.8	76.2	85.5	80.9	78.9	89.1	80.8	87.8	84.2	88.0
Spinach	44.0	66.2	55.1	36.2	57.5	46.9	66.5	63.0	48.8	67.8	58.2	56.0
Parsnip	34.8	76.2	55.5	59.0	90.5	74.8	45.7	65.2	49.0	86.0	67.5	44.8
Tomato	71.5	75.5	73.5	63.0	76.8	69.9	94.7	82.0	66.8	79.8	73.2	72.5
Turnip	36.0	84.8	85.4	88.8	94.2	91.5	101.4	94.3	87.8	90.0	88.9	89.0
AVERAGE	63.6	79.8	71.7	70.8	84.2	77.5	79.1	83.4	71.4	83.6	77.5	80.4
												71.7

* Averages of 16 values

TABLE VII

THE EFFECT OF PELLETING AND SOIL ON THE
AVERAGE DAYS TO EMERGENCE OF 15 VEGETABLES

CROP	MINERAL		MUCK		RATIO P/C	
	P	C	P	C	MINERAL	MUCK
Broccoli	7.61	6.97	7.79	7.16	109.2	108.8
Cabbage	9.84	8.60	9.80	8.93	114.4	109.7
Ch. "	7.88	6.66	7.88	6.76	118.3	116.6
Carrot	14.94	13.58	15.00	13.54	109.2	110.8
Caulifl.	13.21	12.43	12.73	11.52	106.3	110.5
Dill	16.55	14.43	15.59	13.90	114.7	112.2
Kale	11.49	10.26	11.41	10.00	112.0	114.1
Mustard	19.84	19.19	19.22	16.96	103.4	113.3
Onion	17.08	15.54	16.84	14.65	109.9	115.0
Radish	8.71	7.54	8.69	7.49	115.5	116.0
Rutabaga	10.90	9.78	10.81	9.58	111.4	112.8
Spinach	10.62	10.45	11.00	11.24	101.6	97.9
Parsnip	23.08	20.27	21.69	18.25	113.9	118.8
Tomato	15.12	13.20	15.84	13.75	114.5	115.2
Turnip	10.00	10.26	9.09	8.69	97.5	104.6
AVERAGE	13.12	12.00	12.82	10.89	110.1	111.8

FIG. 4. THE RELATIVE INFLUENCE OF SOIL TYPE ON GERMINATION
AND RATE OF EMERGENCE OF PELLETED SEED

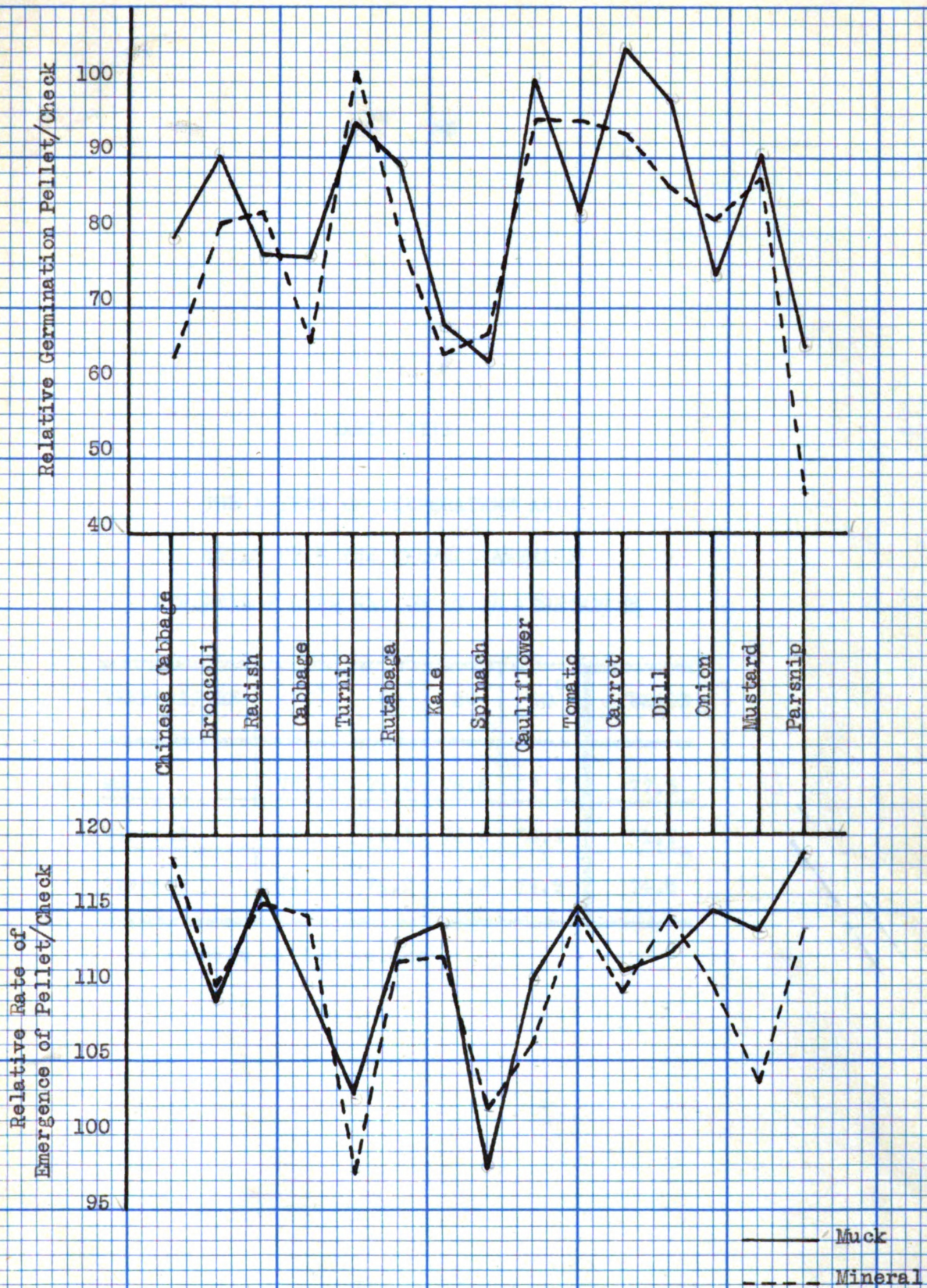


TABLE VIII

THE EFFECT OF TEMPERATURE AND
SOILS UPON THE OVERALL AVERAGE
PERCENTAGE GERMINATION OF 15 VEGETABLES

TEMPERATURE	70°	60°	50°	40°	AVERAGE
Muck	75.5*	78.2	79.6	76.7	77.5
Mineral	67.5	70.1	76.2	73.1	71.7
Average	71.5	74.2	77.9	74.9	74.6

* Average of 120 values

crops the per cent germination on muck soil, at all temperatures, was higher than on mineral soil, and that the optimum temperature for germination on both soils was at 50° F.

PRELIMINARY FIELD INVESTIGATIONS

In order to obtain some observations on the influence of pelleting and coating on germination under field conditions, a small experiment was conducted in May, 1948. The following kinds and varieties of seeds were used.

CROP	VARIETY	TREATMENT
Muskmelon	Honey Rock	Coated
Cucumber	Straight 8	"
Green bean	Giant stringless Gr. Pod	"
Wax bean	Brittle Wax	"
Lima bean	Thorogreen	"
Onion	Downings Yellow Globe	Pelleted
Carrot	Red Cored Chantenay	"
Tomato	Stokesdale	"
Sweet corn	North Star	Coated
" "	Golden Hybrid	"
" "	Golden Security	"

Two 100-seed lots of pelleted or coated seed, which had been treated with a fungicide, were compared with fungicide treated uncoated seed. The small seeded crops were processed to attain a spherical pellet, while the large seeded crops were coated with chemicals without changing the shape of the seed.

The pelleted or coated seed was processed with various fungicides, fertilizers and plant stimulants in the coating material, by Processed Seeds, Inc., Midland, Michigan. The materials used were those that had shown the greatest benefit in previous tests conducted by that company. The effect of the

process on the per cent germination is expressed by the data in the following table:

TABLE IX
PER CENT GERMINATION

	MELON	CUCUMBER	WAX BEAN	GREEN BEAN	LIMA BEAN	ONION	CARROT	TOMATO
Pelleted	78	77	90	93	0	22	14	39
Unpelleted	53	56	81	87	35	41	3	15

SWEET CORN	COATED WITH 2% CUPROCID	COATED WITH 1.5% ARASAN & 3% CHLORONIL	UNCOATED
North Star	52	88	72
Golden Hybrid	42	60	55
Golden Security	72	79	48

Before these plantings had emerged a hard rain tended to crust the soil, which reduced the germination of the small seeded crops.

The germination of melon and cucumber was benefited noticeably by coating the seed, while the germination of coated wax and green beans was only slightly better than that of the uncoated seed. However, onions were reduced in their germination as a result of pelleting. Coated lima beans failed to germinate, possibly due to injury received during the coating process. With sweet corn, the Golden Security variety showed the greatest increase in germination from coating.

DISCUSSION

In this experiment only one lot of each kind of seed was pelleted. Consequently, differences in the relative germination or emergence of the pelleted seed of the 15 different crops may possibly be as much a reflection of variations in the pelleting technique as in the response of a crop to pelleting. The hardness of the pellet or the drying time may have influenced germination. Pelleted cauliflower seed gave a relative germination of 99 per cent, while cabbage gave a relative germination of only 71 per cent (Table V). Perhaps this result is not due so much to the fact that these two crops react differently to pelleting, as to the fact that they were pelleted separately and probably with some slight differences in pelleting procedure. The data presented on Tables I, II and III indicate that the per cent germination of onion, tomato, cabbage and carrot varied markedly. Although different varieties of these crops were used in these treatments, the variation in pelleting technique may be the factor that caused the observed differences in germination. The difference between a relative germination of 99 per cent in carrot and 56 per cent in parsnip, two related crops, may also be due to variations in the pelleting process, and not inherent in the seed.

Varieties of seed ~~can~~ also vary in viability, moisture

content and susceptibility to diseases. Consequently, future work conducted with different lots of seed and different pelleting procedures probably would produce results varying from those found in this experiment. However, the observations relating to the interaction between crop and pelleting under various germinating conditions with respect to soil, soil moisture and temperature should be valid. For example, at 70° F. the relative germination of pelleted cabbage seed was only 63 per cent, while at 40° F. it was 84 per cent of the check seed (Table V). This tendency for a better relative germination at the lower temperature with some crops would probably occur under any condition of pelleting. The relative germination of pelleted tomato seed was 30 per cent better at 70° F. than at 40° F. (Table V). It is apparent then that temperature has a profound influence on the germination of pelleted seed, and shows great variations between crops. In Kotowski's⁽⁵⁾ experiment, the highest germination of cabbage was at 46° F., while with tomato the highest germination was obtained at temperatures between 65° and 77° F. This study indicates that the necessity for germinating seeds at their optimum temperature is accentuated by pelleting. Also at temperatures unfavorable for germination, pelleting further lowers the per cent emergence.

Considering all crops at all factors involved, pelleting delayed emergence 1.2 days, and lowered germination 15 per cent.

This detrimental effect might be caused by a decreased rate of water absorption or a reduced gaseous exchange, or both.

Crocker⁽³⁾ has stated that an accumulation of carbon dioxide or a deficiency of oxygen in the area around the seed caused decreased respiration, and a delay in germination. A delay in emergence of any crop caused by low soil temperature, high soil moisture, or the pelleting process would expose the germinating seed to infection by soil organisms for a longer time. This extended exposure to attack by soil pathogens could be the factor that reduced germination.

In this work an inert pellet was used which contained no seed protectant, plant nutrient, or seed or plant stimulant. In a field experiment, where some of these materials were incorporated into the pellet, germination was substantially better than that found with check seed. The germination of certain varieties of muskmelon, cucumber, wax bean, green bean, tomato and sweet corn seed was markedly benefited by the addition of fungicides and fertilizers to the pellet. Other tests have been conducted that substantiate these results⁽⁴⁾⁽¹³⁾.

Soil type had a significant effect on the germination of the crops used in this work. Muck soil is better aerated than mineral soil, which might explain the increases in germination and rates of emergence on muck soil, that were noted in this test with some crops. Crocker⁽³⁾ suggested that nitrates stimulate

the germination of some seeds, and nitrates are found in fairly large amounts in organic soils. Others have suggested that muck soils contain many growth regulating substances which might stimulate germination. On the average of all crops the relative germination of pelleted seed was 3.8 per cent better on muck than on mineral soil. This may be related to the fact that muck soils, due to their structure, are better aerated. This factor may help the germination of pelleted seed.

Most crops had a higher per cent germination in a soil with a moisture content of 87 per cent field capacity than in soils at 100 per cent field capacity. When the water was added to attain the high moisture content, probably much of the oxygen was forced out of the soil, and this excess water limited the diffusion of more oxygen from the atmosphere. A considerable amount of damping-off was noticed in this experiment. Whetzel⁽¹⁵⁾ found that in saturated soils there was a greater infection from damping-off organisms. In this experiment no actual counts were made of the diseased seedlings at the two moisture levels, but it might be expected that infection was higher on the soil at 100 per cent field capacity. Carrot, cauliflower, onion, dill, parsnip, tomato and turnip showed no significant difference in germination as related to the moisture level of the soil. These crops may not require a high concentration of oxygen for germination, or may not be affected as much

by damping-off organisms. Considering all crops, pelleted seed germinated relatively poorer in soil held at the higher moisture level.

Kotowski⁽⁵⁾ has shown that seed vary in their temperature requirements for germination. This may be due to the fact that seeds differ in their physiological make up, and that temperature regulates the activity, solubilities and absorption of many chemicals including water. Barton⁽¹⁾ has indicated that many seeds absorb varying amounts of water at different temperatures, and that seeds like onion, tomato, lettuce, flax, peanut and pine absorb more water at 50° F. than at any other temperature. This effect might be related to the high germination of seeds obtained at 50° F. in this experiment. Whetzel⁽¹⁵⁾ stated that DeBary's *Pythium* organism requires a temperature between 70° and 86° F. for optimum infection and development, which might suggest another possibility for the high per cent germination at 50° F. Most of the vegetables used in this experiment could be classed as cool season crops, which might offer another explanation for the optimum per cent germination at 50° F.

Crops are affected differently by soil organisms, which in turn are influenced by temperature. The higher rate of emergence at 70° F. is a result of a higher rate of metabolic activity at higher temperatures. The optimum germination obtained at 50° F. might be a compromise between optimum germination temperature and the temperature at which soil organisms are least active.

CONCLUSIONS

The pelleting of vegetable seeds altered their germination and rate of emergence under various conditions. Pelleting affected the per cent germination and time to emergence relative to the unpelleted seed differentially, with respect to crops, germination temperature, soil types, and soil moisture content. The variations in pelleting technique may also effect germination and rate of emergence.

On the basis of 960 observations involving fifteen crops, germinated at four temperatures, on two soil types, at two moisture levels, the following conclusions relative to the effect of pelleting on germination and rate of emergence appear warranted:

1. Pelleting delayed emergence by 1.2 days, and reduced germination by 15 per cent.
2. The pelleting of seed apparently accentuates the necessity for its germination under optimum environmental conditions.
3. The highest per cent germination was obtained on soil with a moisture content of 87 per cent field capacity.
4. Better germinations of most crops were attained on muck soils.
5. Considering all crops, the most rapid rate of

emergence was observed at 70° F., and the highest per cent germination was at 50° F.

The pelleting of the smaller seeded vegetables is economically sound from the standpoint of mechanical planting, if the process can be developed to the point where it does not materially reduce germination. On the bases of preliminary field tests, the possibilities of adding chemicals with the pelleting materials that protect the seed from pathogens, and/or stimulate germination or seedling growth, offer a fertile field for future investigations.

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