EVALUATION OF PRECHILL TREATMENTS FOR PREDICTING FIELD EMERGENCE OF PEANUT SEEDS

By

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Bachelor of Science

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Stillwater, Oklahoma

1972

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
MASTER OF SCIENCE
July, 1974

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PREDICTING FIELD EMERGENCE

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ACKNOWLEDGMENTS

The author wishes to extend special thanks to his wife, Milla, for her patience, encouragement, understanding, and sacrifices which helped to make this thesis possible.

Sincere appreciation is expressed to Dr. James S. Kirby, major adviser, for the advice and constructive criticism received during the course of this study.

Appreciation is expressed to Drs. Lester W. Reed, Robert M. Ahring, and Robert D. Morrison for serving on my graduate committee and for their help in preparing the final manuscript of this thesis. I am grateful to Dr. Robert M. Ahring for his assistance and use of his research laboratory facilities. I am also very grateful to Dr. Robert D. Morrison for his assistance in the use of the Statistical Analysis System Project (S-94) which is supported by the Oklahoma Agricultural Experiment Station.

Gratitude is expressed to Jerry Collins, Charley Lawson, Mike Banks, and Paul Sebesta for their help in preparing the "rolled towel" germination tests. Appreciation is also expressed to all persons involved in the counting of peanut seedlings during the laboratory study of this thesis.

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CHAPTER I

INTRODUCTION

Peanut (Arachis hypogaea L.) seeds require a warm-moist soil at planting for uniform field emergence. In Oklahoma, planting dates vary between May 15 to July 1. These dates allow sufficient time for most Spanish-type peanuts to mature before frost.

Germination and viability of seeds of cultivated peanuts vary greatly from year to year. The value of the seed for planting may be dramatically affected by age and storage conditions. The farmers' risks of crop failure are multiplied when planting seeds of poor quality. Most countries, including the United States, have laws prohibiting the sale of peanut seed unless germination is greater than a statutory minimum percentage. For Oklahoma, the statutory minimum is 70%.

The viability of peanut seeds is usually determined by a germination test. Germination tests utilizing the rolled towel method and carried out according to the widely used Rules for Testing Seeds (Proc. A.O.S.A., 1970) reveal only the percentage of seeds that are viable under near-ideal conditions. A considerable discrepancy may exist between laboratory germination tests and field emergence. This occurs particularly if cool and wet conditions follow field plantings. Several methods of testing germination have been proposed which are different in some respects from the current accepted standard rolled towel method. However, few have been evaluated with respect to field emergence.

High quality seed is essential to enhance the grower's chances of uniform stands. The high fixed cost of planting peanut seeds makes this essential. To insure germination is good, the best possible test is needed. The differences that often occur between laboratory germination tests and field stands give rise to many opinions about the reliability and usefulness of germination tests. Standard procedure germination percentages do not always reflect important differences in quality patterns between sound and unsound seeds (12). The current standard "rolled towel" germination procedure is good but emergence under field conditions is the major test. Research is needed to improve the accepted standard germination test in the area of emergence vigor.

The objective of this study was to evaluate 19 peanut seed lots of varying quality using the standard laboratory test as well as moist prechill treatments prior to utilizing the standard test for predicting field emergence vigor. The information gained may contribute to future improvement of laboratory seed germination procedures for the peanut.

CHAPTER II

LITERATURE REVIEW

Peanut History

Peanuts (Arachis hypogaea L.) are among the leading agricultural crops of the world for the production of oil and plant protein. They rank among the six basic agricultural crops of the United States. Peanuts are grown in the warmer parts of the six major continents (16).

The world peanut crop for 1966 to 1971 was 17.7 million metric tons. The average annual acreage in the United States for this period was 1,439,000 acres producing an average of 1,673 pounds per acre. In a ranking of countries, the United States was third in total peanut production for 1971 accounting for approximately 8% of the world production (8).

Oklahoma ranks sixth in the United States in the production of peanuts and produces about 8.3% of the total crop. Oklahoma produced 106,426 tons on 116,413 acres for an average of 1,829 pounds per acre in 1971, and over 2,000 lbs./A in 1972 (1).

Peanuts are annual herbaceous plants belonging to the Papilionaceae family, a suborder of the larger order Leguminoseae. The origin of the peanut is unknown, although peanuts were known as far back as 950 B.C. They are believed to have been found first in Brazil or Peru, and to have been carried to Africa by early explorers and missionaries.

Peanuts were then introduced from Africa into North America by slave traders in the early colonial days (16).

After fertilization of the flower of the peanut plant, a "peg" develops and grows to reach the soil and pushes 3 to 4 inches below the surface where the fruit or pods are formed. The pods are about 1/2 to 3 inches in length and roughly cylindrical. Of the four peanut market types grown in the United States, the Spanish has the smallest peanuts. Spanish kernels are round with light pink skins, which later become light tan or flesh-colored. The pods usually contain two seeds (16).

Seeds are composed of two massive seed leaves (cotyledons), upper stem axis (epicotyl), young foliage leaves (plumule), lower stem axis (hypocotyl), and primary root (radicle). A thin papery seed coat (testa) covers the seed. In contrast to most papilionaceous legumes, the axis of the embryo proper is straight. All of the leaves and above-ground parts which the normal seedlings will have for the first 2 to 3 weeks of growth are already present in the dormant seed. The epicotyl consists of three buds, one terminal and two cotyledonary laterals. In the terminal bud there are four foliage leaves and in the cotyledonary laterals one or two leaves. In this dormant embryo, 6 to 8 differentiated leaves are already formed and are ready to expand and go to work immediately upon germination and emergence (3).

The seeding rate for planting 36-40 inch row spacings of Spanish peanut seed in Oklahoma is about 60 to 90 pounds per acre. This is based on planting 5 seeds per foot with 90% germination (14).

In the Southwest area, including Louisiana, Arkansas, Texas and Oklahoma, the commercial peanut crop is almost exclusively of the

Spanish type (5). Good peanut yields are obtained on a light sandy loam soil with a growing season of 120 to 140 days combined with an average annual rainfall of 32 to 54 inches and a comparatively high temperature (15).

Special care should be taken during storage to protect seed from insects, mice, or other pests, as well as from high temperatures and high humidities. Peanuts contain such a high percentage of oil, making proper storage essential. The higher the moisture content when peanuts are placed in storage, the faster free-fatty acids develop in the seed. Damaged kernels as well as a high percentage of free-fatty acids are related to low germination (16).

Temperature during storage affects viability. To maintain viability of peanut seeds under storage conditions, moisture should be 6% or lower, and temperature should be held at about 36°F. with a relative humidity of 65%. These conditions maintain quality in Spanish seeds for 2 years (16).

Peanut Germination

The initial water uptake at the start of germination causes the entire peanut seed to swell. Swelling is due mainly to imbibition by the protein, which comprises 20-30% of a peanut seed (10). The awakening step from a dry dormant seed to an active metabolic state usually lasts from minutes to several hours at an optimum temperature with ample moisture in the presence of oxygen. This step is often called the imbibition period during which three major events occur. First is the rapid water uptake by biocolloids in dry seeds. This occurs by first, second and then multiple layers of water molecules

enveloping structural as well as soluble cellular constituents. Second is the activation of macromolecules and organelles, which have been stored or inactivated by the dehydration process of mature seeds. Third is the respiration resulting in adenosine triphosphate (ATP) formation which provides energy for synthesis of substrates, coenzymes, and proteins (enzymes) (9).

After respiration begins during peanut germination, there is an increase in the bulk and function of the mitochondrial fraction (6). Also a pattern of rise and fall of oxygen uptake has been observed in mitochondria isolated from peanut cotyledons (9).

Peanut Composition

Peanut seeds contain about 45-50% oil, 20-30% protein, a good supply of other carbohydrates, and vitamins B and E. The percentage composition of dry weight of isolated protein bodies in dry peanut is 72% protein, 0.2% RNA, 3.1% phytic acid, and 6.9% carbohydrates (9).

The mineral composition of mature peanut seeds is relatively constant for a given variety. The nitrogen (protein) content of seed of the Spanish type has been reported to be higher compared to the Virginia type peanut (5).

Seed proteins are hydrolyzed to peptides and amino acids which can be translocated to the embryo for use in growth and synthesis of new protoplasm (10).

Hoffpauir and Guthrie (5) reported that 87% of the nitrogen of the peanut seed is present as arachin and conarachin.

Of 9.1% nitrogen in peanut material, 8.74% occurred as albuminous substances; including albumen, gluten, and globulin. Two globulins

are arachin and conarachin. About one-fourth of the protein is conarachin which is more soluble than arachin.

Conarachin contains about 3 times as much sulfur as does arachin. Since 87% of the nitrogen of peanuts is present as arachin and conarachin, each containing 18.3% nitrogen, the factor for calculating protein from the nitrogen content is 5.46 (16).

The largest nutritional weakness in peanut protein is its low content of two amino acids essential to both human and animal diets, lysine and methionine. Arachin protein prepared from peanuts contains 1.51% cystine and 0.67% methionine while conarachin contains 2.92% cystine and 2.12% methionine (16).

Peanut protein contains a large amount of nutritionally essential amino acids, of which at least 16 amino acids are found in free form in peanuts (16).

Peanut oil is edible, and has a specific gravity of 0.917-0.920, a refractive index of 1.467-1.470, a saponification number of 186-194, and an iodine number of 85-100. The oil of immature peanut seed has a higher free-fatty acid content than that of mature seed (4). Free-fatty acids do not change during heat treatments involved in the manufacturing of peanut butter or salted peanuts.

Results of 16 varieties and treatments of peanuts using gas chromatographic techniques show the following: (a) peanuts contain from 45 to 49% oil, made up of at least 8 essential fatty acids; (b) peanut oil contains 76 to 82% unsaturated oleic acid and 30 to 35% polyunsaturated linoleic acid; (c) Spanish-type peanuts contain higher percentages of polyunsaturated fatty acids, but are also higher in total saturated fatty acids, giving a wide variation in kind of

fatty acid; (d) runner and Virginia types of peanuts are higher in monounsaturated fatty acids, chiefly oleic (16).

The approximate composition expressed on a molar basis for the glycerides of peanut oil is as follows: oleo-di-saturated 1.0%, mono-saturated-dioleins 11%, mono-saturated-oleino-linoleins 45%, linoleo-dioleins 24%, and triolein 19%. Phosphatides, lecithin, and cephalin settle out of the oil (16).

Most seed lipids are comprised of triglycerides. This seed lipid reserve, triglyceride, is first hydrolyzed to glycerol and fatty acids by the enzyme action of lipases (9). Both soluble and insoluble lipolytic and catalase enzymes are found in peanuts (16).

The composition of oil from Spanish-type peanut seeds is as follows: oleic 52.9%, linoleic 24.7%, palmitic 8.2%, stearic 6.2%, arachidic 4.0%, lignoceric 3.1%, and unsaponifiable material 0.2% (5).

The conversion of fatty reserve to sugars in germinating seeds is a unique feature and is the predominant metabolic activity in storage tissue of fatty seeds. The key enzymes responsible for the conversion are isocitrate lyase and malate synthase (9).

Metabolism during seed germination shows that there is a striking disappearance of reserve materials and a rapid conversion of fat to carbohydrate, especially in high-oil seeds like peanuts. This occurs as a conversion of reserve fat to sucrose in the cotyledons of peanuts (10).

The cotyledons of peanuts naturally contain about 18% carbohydrates and the testa about 1.0%. The starch content of peanuts varies from 0.5 to 5%, depending upon the type, environment, and maturity. Sucrose is reported to make up 4 to 7% of peanuts and phenylosazone of galactose

was found. The pectic substance of peanuts is galactoarabanpectic acid complex. Skin-free peanut seeds contain 2% cellulose. The browning reaction accounts for the principal changes occurring in color and flavor during peanut roasting, and sucrose is the leading carbohydrate involved, with crude fiber being involved only slightly. The cellulose substances react with amino acids at high temperatures to produce carbon dioxide and colors (16).

Peanuts contain about 3% ash, but this amount of ash may vary depending on the different soil types on which they were grown (16).

There are several important vitamins in peanuts. Peanut seeds are an excellent source of riboflavin, thiamine, and nicotinic acid. They also contain considerable amounts of vitamins B and E, but practically no vitamins A, C, or D. The thiamine content of Spanish peanuts with skins is more than 15% higher than the blanched nuts (16).

Seeds usually assimilate phytic acid in the form of magnesium, potassium, and calcium salts during maturation. Adequate supplies of phosphorus, potassium, magnesium, and calcium are needed for the synthesis of metabolites in addition to the needs of functional and structural constituents (particularly ATP, coenzymes, and nucleic acids) for the early growth of seedlings prior to efficient root absorption. Phytic acid comprises about 3.1% of the dry weight of isolated protein bodies from dry peanuts (9).

Seed germination requires a tremendous amount of biological energy (adenosine triphosphate) not only for biogenesis of new cellular constituents in seedlings, but also for the formation of protein-synthesizing machinery in producing enzymes for degradation and conversion of storage compounds. Usually the ATP supply does not appear

to be limiting during germination in a favorable temperature range and with normal oxygen supply. For survival reasons, seeds are provided with mitochondria for ATP production and systems for adenosine diphosphate (ADP) synthesis and production of inorganic phosphate to meet the energy requirement of growth activities. If the environmental conditions are changed to adverse ones, such as very low temperatures and anaerobic conditions, ATP would be limiting and germination arrested (9).

Germination Tests

The Association of Official Seed Analysts' (A.O.S.A.) definition of seed germination is: "In seed laboratory practice, germination is the emergence and development from the seed embryo of those essential structures which, for the kind of seed in question, are indicative of the ability to produce a normal plant under favorable conditions (3)."

Vigor is defined as: "The sum total of all seed attributes which favor stand establishment under unfavorable conditions." The viability of seeds is usually determined by a germination test.

The essential requirements for germination of most seeds are favorable temperature regimes, optimum moisture and oxygen levels. The determination and standardization of substrate moisture is important from the following standpoints: (a) maintenance of a moisture supply for rapid imbibition of water by the seeds and initial seedling growth, (b) maintenance of a favorable relationship between moisture and available oxygen, and (c) the inhibition of saprophytic molds (3). Failure of the germination test to detect certain weaknesses is due to

the lack of the types and magnitudes of stress which the seeds encounter in the field during germination (9).

Peanut seedlings exhibit both hypogeous-epigeous growth. When peanut seeds germinate, the radicle appears first and later the epicotyl expands. The discrepancy between the appearance of the young root and the appearance of the shoot is caused by a striking difference in the initial growth between shoot and root (4).

The standard germination test used today as a measure of seed quality does not always accurately estimate the field emergence. Thought-provoking questions continue to arise concerning the relationship of laboratory germination percentages and field emergence. The comments and questions raised are in search of suitable explanations as to why field emergence in many cases is lower than suggested by laboratory reports (11).

CHAPTER III

MATERIALS AND METHODS

The field studies utilizing two dates of planting 19 different peanut seed lots were conducted at the Agronomy Research Station, Perkins, Oklahoma, under dryland conditions on a Teller loam soil. Dates of planting consisted of one early date, April 30, and an optimum or normal date of June 8, 1973.

A randomized complete block design was used with eight replications. Each plot consisted of a single row 3.05 meters long. Fifty seeds were planted at a depth of 4 cm and spaced equally apart in each row. The rows were 1.02 meters apart. A 0.914 meter alley was used between each replication. The overall experimental area was equivalent to 0.0609 hectare or 615.336 square meters.

Soil moisture content at planting was determined by sampling 32 randomly chosen sites within the experimental area (four sites within each replication). Two samples were taken at each site. The first was taken from the top 15.4 cm of soil and the second between the 15.4 and 30.7 cm depth. The soil moisture cans with lids were weighed individually, labeled, filled with one of the soil moisture samples, then reweighed and recorded. After all filled cans were weighed, the lids were placed at the bottom of the can and the cans were placed inside a Power-O-Matic oven set at 100^{o}C for 24 hours to dry. After the drying period, the cans with lids replaced were allowed to cool to

room temperature and again weighed to determine the soil moisture content. The soil moisture content was determined on a dry basis by the formula:

$$\frac{\text{wet weight - dry weight}}{\text{dry weight}} \times 100$$

After planting, a temperature recorder was placed in the center of the field with 3 probes extending in 3 different directions from the recorder. Each probe was placed about 4 cm. deep in the soil. Also, mercury thermometers were placed in each of the four corners of the field. All thermometer readings were recorded at 7:00 a.m. Daylight Savings Time each day throughout the study.

Two field measurements were used to record emergence and vigor of each seed lot. Three seedling emergence counts were made: May 14, May 21, and June 5. The final count consisted of removing all seedlings per row in each replicate, recording the count and saving the seedlings for dry weight determinations. Paper sacks containing the seedlings were placed in drying ovens set at 48.8^{o}C and allowed to remain for one week. Upon removal, dry weights were read on a Shadograph scale and recorded.

The June 8 field planting was essentially a duplicate of the first involving the same 19 peanut seed lots. The same experimental design and randomization were used. Plot rows were placed immediately adjacent to those of the first planting. When the two planting dates were combined, the data were analyzed as a split-plot in which planting dates were subplots.

Soil moisture content was determined at planting in the same way as previously stated for the first planting. Soil temperature data were collected in the same manner.

Seedling counts were made on June 20, June 27, and July 4. After the final seedling count, the dry weight of the emerged seedlings of each lot were determined as previously described.

The seeds of all lots were treated immediately prior to planting with a fungicide having 75% captan, 1.5% malathion, and 23.5% inert ingredients.

The 19 seed lots listed in Table I are numbered by seed lot, variety, source, and weights/50 seeds.

The Comet #2 seed lot was classified as poor quality on a visual basis. The testae were intact but the kernels appeared damaged with dark-colored stained spots. The seed lot of Comet #3 was also considered poor quality due to the testae being partially removed by a mechanical sheller. The variety Spantex has two Oklahoma peanut accession numbers. Seed lot number 2 was P-1439 and lot number 13 was P-4. P-1439 originated as a single plant selection out of the original Spantex variety (P-4). The other varieties listed by seed lot numbers and sources are distinguishable from one another.

Laboratory evaluation of the 19 seed lots used for study was conducted utilizing 4 replications of 50 seeds per sample per lot. The seed samples of each lot and replication were weighed on a Shadograph scale and recorded. These were later used in the laboratory tests.

Standard rolled towel test procedures were utilized. One sheet of wax paper and two sheets of paper towels, for each sample, were cut to an approximate size of 28 by 36 cm. The wax paper sheet was laid down first, then one water-soaked paper towel was laid on top of the wax paper. The 50 weighed seeds per lot of each replication were evenly

TABLE I

THE NINETEEN PEANUT SEED LOTS USED IN THE GERMINATION STUDIES

Seed Lot Number	Variety and Lot Number	Source	50 Seed Weight (gms)
1	Spancross	Stratford, Oklahoma	17.9
2	Spantex	Stratford, Oklahoma	17.4
3	Starr	Georgia	25.5
4	Florunner	Georgia	36.5
5	Comet	Eakly, Oklahoma	21.0
6	Comet #2	Eakly, Oklahoma	21.3
7	Comet #3	Eakly, Oklahoma	22.4
8	Argentine	Eakly, Oklahoma	18.7
9	Spanhoma	Eakly, Oklahoma	19.6
10	GK 76-67	Georgia	22.4
11	Argentine	Georgia	19.3
12	Spancross #3	Stratford, Oklahoma	17.6
13	Spantex #1	Stratford, Oklahoma	20.9
14	GK 3	Oklahoma	26.4
15	Argentine	Texas	18.4
16	Starr	Texas	19.4
17	Florunner	Texas	25.9
18	Comet	Texas	19.5
19	Spanhoma	Ft. Cobb, Oklahoma	20.6

spaced on the moist toweling with the aid of a spacer board. A second presoaked paper towel was then placed on top of the seeds. The wax paper including the moist paper towels and the seed sample was then rolled and bound at each end with rubber bands, labeled for identification, and placed in an assigned germination or treatment environment. All seeds inside each rolled towel were moistened when the towels appeared dry during the laboratory tests.

Three treatments were used in the rolled towel test: a 10-day and a 5-day prechill and a control receiving no prechill. Samples receiving the prechill treatments were placed at random in a .35 cu meter capacity Revco ultratemperature freezer set at 7°C for the appropriate time. Samples were put in the prechill environment 10 days and 5 days before the start of the actual germination tests so that all treatments of each seed lot could be germinated simultaneously.

Upon removal from the freezer, the rolled towels were placed horizontally on germinator trays and placed inside the germinators on August 25, 1973. One replication of each treatment and seed lot was placed at random on each of 4 tray levels within a germinator. Four Stults germinators were used with two being set at a constant 30°C and two set at alternating 20°-30°C.

Each treatment consisted of 50 seeds per rolled towel, 16 samples per seed lot and 19 seed lots. Thus each treatment involved a total of 15,200 seeds. There were 228 rolled towels in each germinator set at either a constant 30°C or an alternating 16 hours dark at 20°C and 8 hours light at 30°C environment.

Germination counts were made at 5 and 10 days. At each count, seeds that were severely molded were removed. Normal seedlings were

counted and removed also at each count. The official procedure dealing with abnormal seedlings was that they were left and counted at the end of 10-day test period. However, in this study abnormal seedlings were recorded and removed at the 5-day count as well as the 10-day count.

Normal seedlings included those that had: (a) a primary root or a set of secondary or adventitious roots sufficient to anchor the seedlings when grown in soil or sand, provided the hypocotyl was normal; (b) a fairly well-developed hypocotyl with no prominent breaks or deep lesions which might interfere with the conducting tissues; (c) a plumule with at least one leaf and an intact growing point; and (d) slight infection by fungi, provided the essential seedling parts had not been seriously damaged and appeared to be able to carry on their normal functions at the time of evaluation (7).

Seedlings were classified abnormal if they had: (a) no primary root or no well-developed secondary or adventitious roots; (b) a malformed hypocotyl which was either curled, shortened, or thickened or had severe open splits; (c) no epicotyl, or one without the growing point, with or without leaves; (d) decayed epicotyl, provided the decay had spread from the rotted cotyledons of the developing seedlings; and (e) various combinations of the above (7).

The analyses of variance for the variables were calculated on the Statistical Analysis System at the Oklahoma State University Computer Center (2).

The percent germination in the laboratory was used to predict the field emergence of each field planting. The general prediction equation,

$Y=A+BX+E$, was used, where Y is the observed field emergence; X is the observed laboratory germination; E is the random error associated with Y; B is the slope of the line; and A is the intercept. Table XI shows the regression coefficients of the equations for each of the prechill-germinator temperature treatment combinations.

CHAPTER IV

RESULTS AND DISCUSSION

Soil Moisture

Soil moisture content of the upper 15.4 cm of the seed bed at the first planting date was 13.7%. The 15.4 to 30.7 cm depth contained 16.7% moisture. The upper 15.4 cm of soil at the second planting date had a moisture content of 13.3% while the lower 15.4 to 30.7 cm contained 16.5% moisture. The resulting mean for both depths for the first planting was 15.2% moisture compared to 14.9% moisture for the second planting. The difference between the upper and lower depths for each field planting was significant at the 0.01 level of probability. There was no difference between planting dates for soil moisture content at either level.

Rainfall occurring after the first planting date and before the final seedling counts were made was 11.94 cm. This compared to 3.23 cm of rain following the second planting date and before the final seedling counts (Table X).

Soil Temperature

The average daily soil temperature at a 4 cm depth at 7:00 a.m. (Figure 1) shows that only four days were as high as 20°C following the first planting date until the final count was made. Only 3 days following the second date of planting were below 20°C (Figure 2).

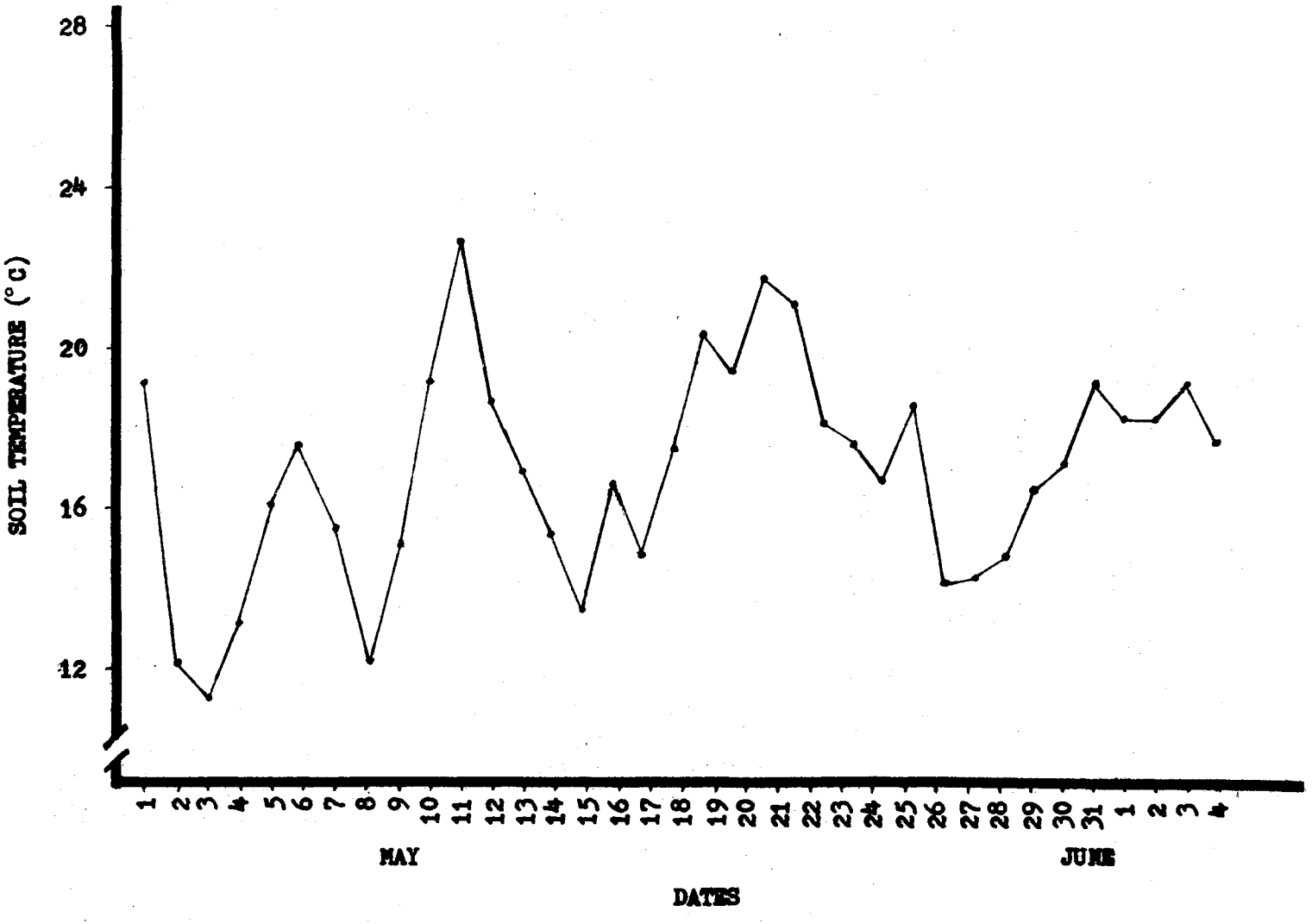

Figure 1. Soil Temperature at a 4 cm Depth at 7:00 a.m. for the Days of the First Field Planting, Perkins, 1973

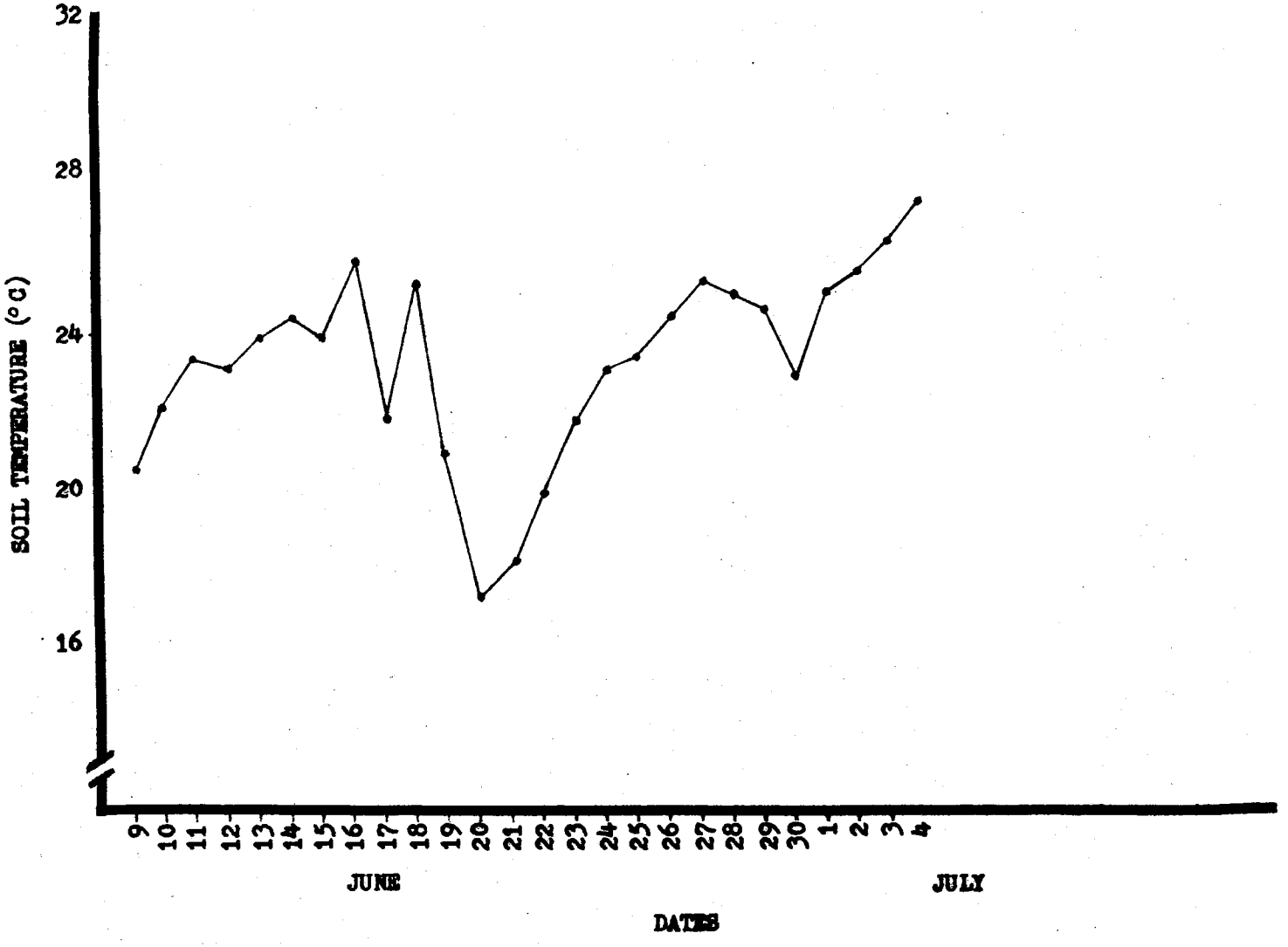

Figure 2. Soil Temperature at a 4 cm Depth at 7:00 a.m. for the Days of the Second Field Planting, Perkins, 1973

Field Emergence

The 19 seed lots were purposely selected to give a wide range in seed quality. The selection was apparently successful since emergence from the first field planting ranged from a low of 1% (lot 1) to a high of 88.2% (lot 17) as shown in Table II.

The emergence percentages for the first field planting averaged over the 19 seed lots for the first, second, and final counts were 35.6%, 51.2% and 61.2%, respectively (Table II). The analysis of variance for each of the three counts indicated that the seed lots were significantly different at the 0.01 level of probability. A study of the data in Table II indicated a slight trend for the rate of emergence to be faster for those seed lots which had a higher final emergence count.

In the second field planting when the soil temperatures were more optimum for peanut seed germination, seed lot 1 again had the lowest field emergence with 1.2%, while seed lot 17 again had the highest with 94.2% emergence under field conditions (Table III). For the three counts made, the nineteen seed lots averaged 49.8%, 53.8%, and 62.4%, respectively. The analysis of variance for each of the three counts again indicated that the seed lots were significantly different at the 0.01 level of probability. The trend for the better seed lots to have faster rates of emergence was not as noticeable in the later planting. The increased level of germination at the first count of the second planting was a reflection of the much higher soil temperatures during this period.

TABLE II

MEAN NUMBER OF NORMAL SEEDLINGS EMERGING FROM SAMPLES OF 50 SEEDS PLANTED FOR EACH OF 19 PEANUT SEED LOTS IN THE EARLY (APRIL 30) FIELD PLANTING, PERKINS, 1973

Seed Lot Number	Seedling Counts		
	First (May 14)	Second (May 21)	Final (June 5)
1	0.0[1]	0.0	0.5
2	0.0	0.8	0.9
3	8.9	17.0	20.8
4	5.5	14.4	18.6
5	25.9	37.6	41.4
6	28.0	36.1	39.8
7	12.8	19.4	22.5
8	27.6	36.0	42.3
9	26.4	35.4	41.9
10	12.8	26.4	31.1
11	15.4	23.5	28.3
12	0.0	2.3	6.0
13	22.8	33.1	41.1
14	17.9	31.1	34.1
15	28.8	33.3	41.8
16	27.8	34.1	41.4
17	22.3	37.9	44.1
18	33.4	37.0	43.3
19	22.1	31.9	41.0
Mean	17.8	25.6	30.6

[1]Each value is the mean of 8 replications.

TABLE III

MEAN NUMBER OF NORMAL SEEDLINGS EMERGING FROM SAMPLES OF 50 SEEDS PLANTED FOR EACH OF 19 PEANUT SEED LOTS IN THE LATE (JUNE 8) FIELD PLANTING, PERKINS, 1973

Seed Lot Number	Seedling Counts		
	First (June 20)	Second (June 27)	Final (July 4)
1	0.4[1]	0.4	0.6
2	0.5	0.9	0.9
3	16.4	19.9	21.9
4	10.4	14.5	16.9
5	31.0	30.5	38.4
6	32.6	34.4	38.4
7	21.4	23.0	25.6
8	33.3	34.4	41.8
9	30.4	31.8	38.6
10	21.6	27.3	28.8
11	22.8	26.8	31.6
12	2.5	7.0	10.5
13	30.1	33.6	37.3
14	27.8	33.6	34.4
15	35.4	35.1	45.0
16	39.6	39.6	47.0
17	41.4	41.8	47.1
18	39.1	39.8	44.9
19	36.0	35.8	44.1
Mean	24.9	26.9	31.2

[1]Each value is the mean of 8 replications.

The split-plot analysis of variance revealed no significant difference between the two planting dates for final emergence but again indicated highly significant differences among the seed lots.

The first or early planting was in the ground 37 days before the final seedling counts were made and seedlings pulled for dry matter (DM) determination compared to 27 days for the later planting. The longer time interval between planting and final counts made on the early planting was again very likely a reflection of the colder soil.

At each count in both field plantings, the abnormal seedlings were recorded. A few apparent abnormal seedlings were observed at the first two counts of the early planting, but none were observed at the final count, nor at any of the three counts of the later planting.

Dry Matter Weight

The mean of the nineteen seed lots for the entire plant (seedling) dry matter weights of the early planting date was 37.1 grams, compared to 46.1 grams for the later planting (Table IV). The analyses of variance for the dry matter revealed that the 19 seed lots were significantly different at the 0.01 level of probability for both field planting dates in seedling vigor.

Fifty Seed Weight

Seed weights were determined as a matter of record to help describe the nineteen seed lots used in the studies (Table I). The analyses of variance indicated significant differences among the seed lots for seed weight. In this study, seed size had no apparent influence on laboratory germinability or field emergence.

igure 3. Effect of Planting Date on the Percent Germination (Normal Seedlings) for the Nineteen Peanut Seed Lots in the Field Study, Perkins, 1973

igure 3. Effect of Planting Date on the Percent Germination (Normal Seedlings) for the Nineteen Peanut Seed Lots in the Field Study, Perkins, 1973

igure 3. Effect of Planting Date on the Percent Germination (Normal Seedlings) for the Nineteen Peanut Seed Lots in the Field Study, Perkins, 1973

TABLE IV

MEAN DRY MATTER PRODUCED FROM EACH OF 19 PEANUT SEED LOTS FOR THE TWO FIELD PLANTINGS, PERKINS, 1973

Seed Lot Number	Dry Matter Weight (grams)	
	Early Planting	Late Planting
1	0.4[1]	0.8
2	1.3	1.7
3	27.2	31.4
4	30.8	29.4
5	55.1	54.3
6	53.6	51.3
7	27.5	42.7
8	46.4	51.2
9	46.9	55.4
10	35.7	38.5
11	30.2	36.0
12	3.8	10.0
13	44.0	52.0
14	44.8	60.0
15	49.4	67.7
16	41.8	70.7
17	66.4	86.0
18	53.9	68.6
19	45.2	68.6
Mean	37.1	46.1

[1]Each value is the mean of 8 replications.

Laboratory Germination

The percentages of normal seedlings averaged over the 19 seed lots for the 0, 5, and 10-day prechill treatments were 47.4%, 31.0%, and 34.4%, respectively, as shown in Table V. These data are graphically illustrated in Figure 4. The slightly higher overall germination value for the 10-day prechill compared to the 5-day prechill is not fully understood. The analysis of variance in Table VII indicates a highly significant difference among the prechill treatments; however, from the means the 0-day prechill was considerably different from the 5 and 10-day prechill treatments. The slight difference between the 5 and 10-day may be random error and not a real difference.

Statistical analysis of total normal germination indicated highly significant differences among seed lots, among prechill treatments, and for the seed lot x prechill treatment interaction. Differences occurred between germination temperatures, among seed lots, among prechill treatments, and for the seed lot x prechill treatment interaction for abnormal seedling germination at the 0.01 level of probability (Table VII). Mean numbers of abnormal seedlings are shown in Table VI.

The germination of normal seedlings at the 5-day count averaged over the 3 prechill treatments was 18.8%, while the 10-day count was also 18.8%, indicating that as many seeds germinated between the sixth and tenth days as had germinated in the first 5 days (Table VIII). Appendix Tables XII, XIII, and XIV show the 5 and 10-day counts for the individual prechill treatments. The 0-day prechill treatment, i.e., no exposure to prechill stress, resulted in much higher counts at the end of 5 days than did the 5 and 10-day prechill treatments.

TABLE V

MEAN NUMBER OF NORMAL SEEDLINGS GERMINATING FROM SAMPLES OF 50 SEEDS TESTED FOR EACH OF 19 PEANUT SEED LOTS EXPOSED TO THREE PRECHILL TREATMENTS, STILLWATER, 1973

Seed Lot Number	Days of Prechill			Mean
	0	5	10	
1	0.3[1]	0.1	0.2	0.2
2	0.0	0.0	0.0	0.0
3	11.0	6.1	1.3	6.1
4	16.8	8.9	3.8	9.8
5	29.8	16.1	16.8	20.9
6	39.3	26.7	18.9	28.3
7	26.2	13.7	10.4	16.8
8	38.3	28.3	17.4	28.0
9	35.8	21.7	30.3	29.3
10	13.3	9.3	6.6	9.7
11	15.8	12.0	5.2	11.0
12	3.8	1.0	0.2	1.7
13	27.3	12.2	12.4	17.3
14	27.9	25.3	23.4	25.5
15	34.6	17.5	30.9	27.7
16	32.6	22.3	33.4	29.4
17	34.6	24.9	37.9	32.5
18	32.8	22.8	43.9	33.2
19	29.8	26.3	34.5	30.2
Mean	23.7	15.5	17.2	18.8

[1]Each value is the mean of 16 observations (8 replications of 50 seeds per seed lot for each of two germinator temperature treatments).

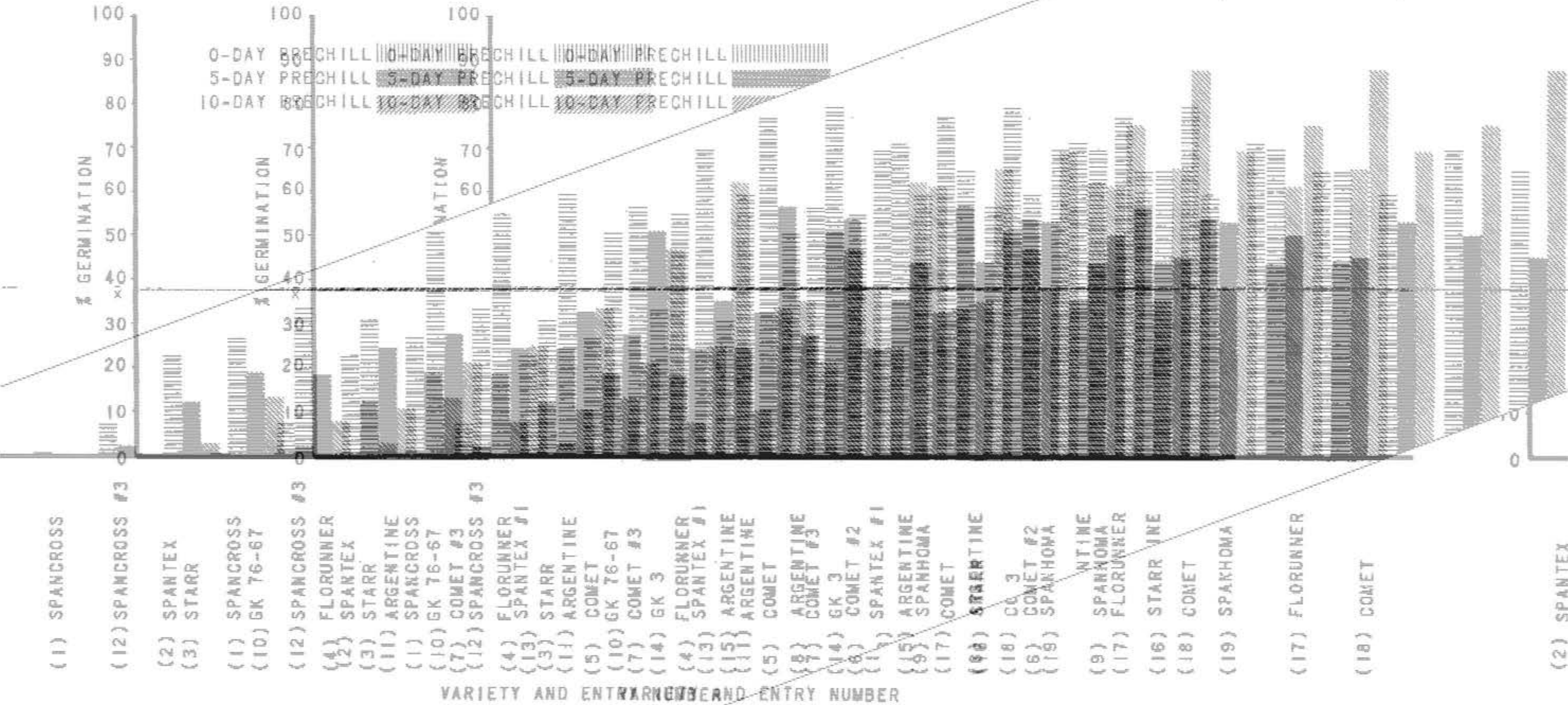

Figure 4. Effect of Prechill Treatment on the Percent Germination (Normal Seedlings) of the Nineteen Peanut Seed Lots in Seedling Study, Stillwater, 1973

TABLE VI

MEAN NUMBER OF ABNORMAL SEEDLINGS GERMINATING FROM SAMPLES OF 50 SEEDS TESTED FOR EACH OF 19 PEANUT SEED LOTS EXPOSED TO THREE PRECHILL TREATMENTS, STILLWATER, 1973

Seed Lot Number	Days of Prechill			Mean
	0	5	10	
1	0.8[1]	0.4	0.9	0.7
2	0.2	0.3	0.1	0.2
3	17.4	18.1	13.1	16.2
4	17.9	15.6	12.7	15.4
5	16.9	25.3	19.1	20.4
6	9.6	16.5	23.6	16.6
7	14.5	19.9	19.2	17.9
8	9.6	19.4	23.6	17.6
9	13.4	24.7	14.6	17.6
10	24.3	23.0	18.4	22.0
11	22.1	23.5	22.4	22.7
12	7.1	2.1	1.2	3.5
13	17.5	24.9	20.5	21.0
14	14.2	16.4	15.8	15.5
15	15.3	30.9	17.2	21.1
16	17.0	26.4	16.1	19.9
17	14.0	22.9	9.3	15.4
18	16.6	26.4	5.3	16.1
19	18.7	21.8	11.9	17.5
Mean	14.1	18.9	14.0	15.6

[1]Each value is the mean of 16 observations (8 replications of 50 seeds per seed lot for each of two germinator temperature treatments).

TABLE VII

THE ANALYSES OF VARIANCE FOR TOTAL NORMAL AND ABNORMAL GERMINATION FROM 19 PEANUT SEED LOTS EXPOSED TO THREE PRECHILL TREATMENTS AND PLACED IN GERMINATORS SET AT TWO DIFFERENT TEMPERATURE REGIMES, STILLWATER, 1973

Source	d.f.	Mean Squares Normal	Abnormal
Total	911	208.2	112.1
Temperature (T)	1	894.1	479.1**
Error a			
Germinator (G) in T	2	517.6	73.0
Shelf (S)	3	536.6	364.0
Error b	9	222.6	543.4
T x S +	3	145.7	222.5
G x S in T	6	261.1	703.7
Seed Lot (L)	18	6486.7**	2175.8**
Prechill Treatment (P)	2	5577.6**	2407.4**
L x P	36	468.3**	318.1**
T x L	18	56.7	184.8
T x P	2	25.5	127.2
T x L x P	36	48.3	45.8
Error c	112	41.3	47.6
G x L in T +	36	40.2	57.7
G x P in T +	4	21.9	91.8
G x L x P in T	72	42.9	40.0
Error d	672	47.5	43.9
S x L +	54	75.4	60.6
S x P +	6	86.1	78.4
S x L x P +	108	39.5	38.5
G x S x L in T +	108	46.4	57.9
G x S x P in T +	12	92.5	31.8
G x S x L x P in T +	216	41.6	38.1
T x S x L +	54	36.4	49.1
T x S x P +	6	84.1	59.8
T x S x L x P	108	50.5	34.4

**Indicates significance at the 0.01 level of probability.

TABLE VIII

MEAN NUMBER OF NORMAL AND ABNORMAL SEEDLINGS GERMINATED ON 5-DAY AND 10-DAY COUNTS FROM SAMPLES OF 50 SEEDS TESTED FOR EACH OF 19 PEANUT SEED LOTS EXPOSED TO THREE PRECHILL TREATMENTS, STILLWATER, 1973

Seed Lot Number	5-Day Count		10-Day Count		Total	
	Normal	Abnormal	Normal	Abnormal	Normal	Abnormal
1	0.2[1]	0.2	0.0	0.5	0.2	0.7
2	0.0	0.0	0.0	0.2	0.0	0.2
3	2.4	1.5	3.7	14.7	6.1	16.2
4	4.1	3.2	5.7	12.2	9.8	15.4
5	11.4	2.4	9.5	18.0	20.9	20.4
6	14.3	3.3	14.0	13.3	28.3	16.6
7	11.6	6.5	5.2	11.3	16.8	17.8
8	13.5	4.2	14.5	13.4	28.0	17.6
9	13.5	4.5	15.8	13.1	29.3	17.6
10	2.6	1.8	7.1	20.2	9.7	22.0
11	4.0	1.7	7.0	21.2	11.0	22.9
12	0.6	0.5	1.1	2.9	1.7	3.4
13	5.5	2.7	11.8	18.3	17.3	21.0
14	12.8	4.7	12.7	10.8	25.5	15.5
15	16.4	7.3	11.2	13.9	27.6	21.2
16	17.0	5.7	12.4	14.2	29.4	19.9
17	16.0	3.9	16.5	11.5	32.5	15.4
18	19.3	4.6	13.9	11.5	33.2	16.1
19	14.3	4.2	15.9	13.3	30.2	17.5
Mean	9.4	3.3	9.4	12.3	18.8	15.6

[1]Each value is the mean of 48 observations (8 replications of 50 seeds per seed lot for each of two germinator temperatures and three prechill treatments).

This was basically true for all seed lots, however, the better seed lots had a greater proportion of their seeds germinated at the end of 5 days. When the seed lots were exposed to the 5-day prechill treatment, the poor seed lots had a greater portion germinating in the second 5-day period. The better seed lots averaged the same at each count but some lots had more seeds germinated in the first 5 days while other lots had more germinated in the second 5-day period. With few exceptions, all seed lots exposed to the 10-day prechill treatment were slower in germinating as evidenced by the higher 10-day counts.

The germination of abnormal seedlings at the 5 and 10-day counts did change. The second 5 days of the 10-day test showed 24.6% abnormal seedlings compared to 6.6% for the first 5 days.

The analyses of variance for the 5 and 10-day normal seedling germination revealed highly significant differences among seed lots, among prechill treatments and for the seed lot x prechill treatment and temperature x seed lot interactions. The analysis for the 10-day count also indicated highly significant differences between germination temperatures and among shelves in the germinators (Table IX). The analysis of variance for 5-day abnormal germination indicated shelves in germinators, seed lots and prechill treatments to be significantly different at the 0.01 level of probability (Table IX). The analysis of the 10-day abnormal count gave highly significant differences among seed lots, among prechill treatments and for the seed lot x prechill treatment interaction.

The regression coefficients involving the 0-day or no prechill treatment, which is equivalent to the current standard laboratory

TABLE IX

THE ANALYSES OF VARIANCE FOR 5 AND 10-DAY NORMAL AND 5 AND 10-DAY ABNORMAL SEEDLING COUNTS FROM 19 PEANUT SEED LOTS EXPOSED TO THREE PRECHILL TREATMENTS AND PLACED IN GERMINATORS SET AT TWO DIFFERENT TEMPERATURE REGIMES, STILLWATER, 1973

Source	d.f.	5-Day		10-Day	
		Normal	Abnormal	Normal	Abnormal
Total	911	124.3	26.0	109.0	112.1
Temperature (T)	1	3560.5	735.5	8023.1**	2401.8
Error a					
Germinator (G) in T	2	1484.5	793.3	604.4	1184.2
Shelf (S)	3	2339.7	1338.9**	3047.8**	798.4
Error b	9	376.0	216.8	630.2	710.6
T x S +	3	523.2	50.6	1179.0	296.8
G x S in T	6	302.4	300.1	355.7	917.4
Seed Lot (L)	18	2045.3**	203.3**	1471.2**	1602.6**
Prechill Treatment (P)	2	5773.0**	356.0**	242.2**	3283.7**
L x P	36	236.2**	13.8	186.5**	355.2**
T x L	18	172.8**	27.0	210.9**	126.0
T x P	2	43.9	1.4	5.9	109.8
T x L x P	36	47.7	7.7	62.8	46.3
Error c	112	40.1	14.4	53.8	57.1
G x L in T +	36	69.1	23.2	74.5	77.0
G x P in T +	4	55.8	27.5	94.2	109.5
G x L x P in T	72	24.8	9.3	41.2	44.2
Error d	672	44.7	12.1	43.8	44.3
S x L +	54	94.7	33.3	98.7	61.9
S x P +	6	116.2	42.5	170.0	35.5
S x L x P +	108	35.4	7.9	43.5	41.9
G x S x L in T +	108	44.9	16.0	41.4	51.7
G x S x P in T +	12	100.4	8.5	43.8	23.1
G x S x L x P in T+	216	32.0	8.9	30.4	36.6
T x S x L +	54	45.5	9.0	53.1	53.9
T x S x P +	6	125.0	7.8	88.5	75.6
T x S x L x P	108	39.2	8.5	32.0	42.2

**Indicates significance at the 0.01 level of probability.

germination test procedure, were high and would appear to give a better prediction of field emergence than would either the 5 or 10-day prechill treatments. However, if the abnormal seedlings at the 5-day count had not been removed and had been allowed to remain until the final count, the percentage normal laboratory germination could possibly have been greater. A considerable number of seedlings counted as abnormal at the 5-day counts would in all likelihood have developed into normal seedlings by the end of 10 days.

CHAPTER V

SUMMARY AND CONCLUSIONS

Experiments were conducted near Perkins, Oklahoma, in the late spring and early summer months of 1973, to determine field emergence and vigor of 19 different peanut seed lots planted at early and late planting dates. During the later summer months of 1973, at Stillwater, Oklahoma, a laboratory experiment was conducted to evaluate the effects of 0, 5 and 10-day moist prechill treatments at 5-10^{o}C on germination of each seed lot. The primary objective was to develop or find a laboratory germination test that would more accurately reflect seed quality and predict field emergence.

Soil moisture in the two field plantings was relatively the same. Significant differences were observed only between the top 15.4 cm of soil and the next 15.4 cm of soil at each field planting date. Soil temperatures for the first field planting were considerably lower than for the second field planting.

There was no significant difference in emergence of normal seedlings between the early and late field plantings. Highly significant differences were obtained among the nineteen seed lots in all studies conducted. Significant differences in seed weights were noted among the seed lots involved; however, in this study, seed weight or size appeared to have no influence on germinability.

The three prechill treatments studied in the laboratory were also significantly different at the 0.01 level of probability. The stress of prechilling for 5 and 10 days reduced the percentage of normal seedlings compared to no prechilling.

From these research results on peanut germination procedures, it appears that the actual planting quality of the 19 peanut seed lots was more accurately estimated by the 0-day prechill, which is equivalent to the standard laboratory procedure presently being used. Neither the 5 nor the 10-day prechill treatments were as useful for predicting field emergence. The prediction of field emergence based on laboratory germination tests may have been closer if the abnormal seedlings at the 5-day count had not been removed and had been allowed to remain until the final count. A considerable number of seedlings counted as abnormal at the 5-day counts would in all likelihood have developed into normal seedlings by the end of 10 days.

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APPENDIX

TABLE X

RAINFALL DATA--PERKINS, OKLAHOMA (1973)

Early Planting		Late Planting	
Date	Centimeter	Date	Centimeter
May 6	1.40	June 14	0.46
May 21	0.20	June 19	2.26
May 23	2.69	June 29	0.51
May 24	1.50		
May 28	0.51		
May 30	0.43		
May 31	2.62		
June 2	2.11		
June 4	0.48		
Total	11.94	Total	3.23

TABLE XI

REGRESSION VALUES USED FOR PREDICTING FIELD EMERGENCE FROM LABORATORY DATA

Germinator Temperatures °C	Prechill Treatments	Field Plantings	A	B	Error of Estimate d.f.=17	R^2
30	0-Day	1	7.46	1.03	44.98	0.81
30	5-Day	1	10.18	14.06	52.21	0.78
30	10-Day	1	16.27	0.86	77.43	0.67
30	0-Day	2	8.52	1.01	50.67	0.78
30	5-Day	2	10.43	14.37	43.85	0.81
30	10-Day	2	16.36	0.89	63.67	0.73
20-30	0-Day	1	4.09	1.06	28.48	0.88
20-30	5-Day	1	9.49	1.27	65.99	0.72
20-30	10-Day	1	16.67	0.78	93.08	0.60
20-30	0-Day	2	4.95	1.05	30.65	0.87
20-30	5-Day	2	10.22	1.26	66.38	0.72
20-30	10-Day	2	16.48	0.82	74.26	0.68

TABLE XII

MEAN NUMBER OF NORMAL AND ABNORMAL SEEDLINGS GERMINATED ON 5-DAY AND 10-DAY COUNTS FROM SAMPLES OF 50 SEEDS TESTED FOR EACH OF 19 PEANUT SEED LOTS EXPOSED TO 0-DAY PRECHILL TREATMENT, STILLWATER, 1973

Seed Lot Number	5-Day Count		10-Day Count		Total	
	Normal	Abnormal	Normal	Abnormal	Normal	Abnormal
1	0.3[1]	0.1	0.0	0.6	0.3	0.7
2	0.0	0.1	0.0	0.1	0.0	0.2
3	4.9	2.5	6.1	14.9	11.0	17.4
4	8.8	5.1	8.0	12.8	16.8	17.9
5	22.3	4.3	7.5	12.6	29.8	16.9
6	28.5	4.8	10.8	4.8	39.3	9.6
7	19.5	7.3	6.7	7.2	26.2	14.5
8	23.3	5.9	14.9	3.7	38.2	9.6
9	22.8	5.6	13.0	7.8	35.8	13.4
10	4.8	3.6	8.4	20.7	13.2	24.3
11	6.6	2.6	9.2	19.5	15.8	22.1
12	1.2	0.9	2.6	6.2	3.8	7.1
13	12.3	5.2	15.1	12.3	27.4	17.5
14	15.8	6.0	12.1	8.2	27.9	14.2
15	23.0	10.5	11.6	4.8	34.6	15.3
16	22.2	5.4	10.4	11.6	32.6	17.0
17	20.3	4.5	14.3	9.5	34.6	14.0
18	21.4	7.1	11.3	9.5	32.7	16.6
19	17.0	4.3	12.8	14.4	29.8	18.7
Mean	14.5	4.5	9.2	9.5	23.7	14.0

[1]Each value is the mean of 16 observations (8 replications of 50 seeds per seed lot for each of two germinator temperatures).

TABLE XIII

MEAN NUMBER OF NORMAL AND ABNORMAL SEEDLINGS GERMINATED ON 5-DAY AND 10-DAY COUNTS FROM SAMPLES OF 50 SEEDS TESTED FOR EACH OF 19 PEANUT SEED LOTS EXPOSED TO 5-DAY PRECHILL TREATMENT, STILLWATER, 1973

Seed Lot Number	5-Day Count		10-Day Count		Total	
	Normal	Abnormal	Normal	Abnormal	Normal	Abnormal
1	0.1[1]	0.2	0.0	0.2	0.1	0.4
2	0.0	0.0	0.0	0.3	0.0	0.3
3	1.9	1.2	4.2	16.9	6.1	18.1
4	1.8	2.3	7.1	13.3	8.9	15.6
5	7.4	1.8	8.8	23.5	16.2	25.3
6	7.6	2.7	19.1	13.8	26.7	16.5
7	9.0	6.9	4.7	13.0	13.7	19.9
8	12.4	4.6	15.8	14.9	28.3	19.5
9	8.6	4.1	13.1	20.6	21.7	24.7
10	1.6	0.7	7.7	22.3	9.3	23.0
11	4.3	1.4	7.7	22.1	12.0	23.5
12	0.4	0.7	0.6	1.4	1.0	2.1
13	2.5	1.8	9.7	23.2	12.2	25.0
14	12.0	3.9	13.3	12.6	25.3	16.5
15	10.0	5.8	7.5	25.2	17.5	31.0
16	14.4	5.6	7.9	20.8	22.3	26.4
17	11.8	4.2	13.2	18.8	25.0	23.0
18	14.1	4.1	8.8	22.3	22.9	26.4
19	12.1	3.9	14.3	17.9	26.4	21.8
Mean	6.9	2.9	8.6	15.9	15.5	18.8

[1]Each value is the mean of 16 observations (8 replications of 50 seeds per seed lot for each of two germinator temperatures).

TABLE XIV

MEAN NUMBER OF NORMAL AND ABNORMAL SEEDLINGS GERMINATED ON 5-DAY AND 10-DAY COUNTS FROM SAMPLES OF 50 SEEDS TESTED FOR EACH OF 19 PEANUT SEED LOTS EXPOSED TO 10-DAY PRECHILL TREATMENT, STILLWATER, 1973

Seed Lot Number	5-Day Count		10-Day Count		Total	
	Normal	Abnormal	Normal	Abnormal	Normal	Abnormal
1	0.2[1]	0.3	0.0	0.6	0.2	0.9
2	0.0	0.0	0.0	0.1	0.0	0.1
3	0.4	0.8	0.9	12.3	1.3	13.1
4	1.8	2.2	1.9	10.5	3.7	12.7
5	4.5	1.2	12.3	17.9	16.8	19.1
6	6.6	2.5	12.3	21.3	18.9	23.8
7	6.2	5.4	4.3	13.8	10.5	19.2
8	4.8	2.1	12.6	2.15	17.4	23.6
9	9.0	3.8	21.3	10.9	30.3	14.7
10	1.4	1.1	5.2	17.4	6.6	18.5
11	1.1	0.9	4.1	21.5	5.2	22.4
12	0.1	0.0	0.1	1.2	0.2	1.2
13	1.6	1.1	10.8	19.4	12.4	20.5
14	10.7	4.1	12.8	11.6	23.5	15.7
15	16.3	5.6	14.6	11.6	30.9	17.2
16	14.4	6.0	18.9	10.1	33.3	16.1
17	15.8	2.9	22.1	6.4	37.9	9.3
18	22.3	2.4	21.6	2.9	43.9	5.3
19	13.7	4.4	20.8	7.4	34.5	11.8
Mean	6.9	2.5	10.3	11.5	17.2	14.0

[1]Each value is the mean of 16 observations (8 replications of 50 seeds per seed lot for each of two germinator temperatures).

VITA

William Dean Branch

Candidate for the Degree of

Master of Science

Thesis: EVALUATION OF PRECHILL TREATMENTS FOR PREDICTING FIELD EMERGENCE OF PEANUT SEEDS

Major Field: Agronomy

Biographical:

Personal Data: Born at Duncan, Oklahoma, September 14, 1950, the son of Bill and Effie Branch.

Education: Attended Meridian Grade School at Sunray Village, Oklahoma. Received high school diploma from Comanche High School, Comanche, Oklahoma, 1968. Attended Southeastern State College, Durant, Oklahoma, 1968-1969. Received the Bachelor of Science degree from Oklahoma State University in 1972. Completed requirements for the Master of Science degree at Oklahoma State University, July, 1974.

Experience: Reared and worked on a farm near Sunray, Oklahoma, until after high school graduation, then during the summer months until 1973; half-time research assistant, Department of Agronomy, Oklahoma State University, 1972-1974.

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