STAND ESTABLISHMENT OF WINTER WHEAT
IN OKLAHOMA, A SURVEY

BY

ROGER STOCKTON

Bachelor of Science

Panhandle State University

Goodwell, 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
May, 1994

OKLAHOMA STATE UNIVERSITY

STAND ESTABLISHMENT OF WINTER WHEAT

IN OKLAHOMA, A SURVEY

Thesis Approved:

Eugene G. Krenzer, Jr.

Thesis Adviser

John B Solie

Kevin J. Donnelly

Thomas C. Collins

Dean of the Graduate College

ACKNOWLEDGMENTS

I wish to express my heartfelt appreciation to my major advisor, Dr. Eugene G. Krenzer, for his help and support in all phases of my graduate work and his faithful fellowship and support of my entire family during the difficult time of my son's illness and death. I have gained much knowledge of and commitment to, agronomic research from him. Special thanks to Dr. Kevin Donnelly who supervised my work as a teaching assistant in the Agronomy dept. and increased my knowledge of teaching in general and plant physiology in particular. Thanks to Dr. John Solie for increasing my knowledge in the area of engineering of planting equipment. Thanks also to Dr. Mark Payton, who answered my statistical questions and helped me understand what the numbers meant.

My deepest thanks and appreciation go to my entire family for their support and understanding in my continued education. To my wife, Rosie, and my daughters, Jennifer and Jessica, I am eternally grateful for the faith, patience and moral support, without which this would have been an impossible task.

I would also like to thank the various OSU county extension agriculture agents who worked with me surveying producers and, of course, the wheat producers of Oklahoma.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER I

INTRODUCTION

Timely establishment of a crop is the first step to optimum production and winter wheat (Triticum aestivum, L.) production in Oklahoma illustrates this point clearly. It is critical for two reasons. Wheat forage is grazed during the winter months on as much as 55% of Oklahoma's six to seven million wheat acres (Thompson, 1990). An early, dense, vigorous stand is essential for profitable grazing. The second reason is that adequate soil moisture for germination will frequently only be available for one to two weeks during the normal planting period. If desired plant population is not achieved during this time, it may be several weeks before rainfall adequate for germination is received.

In Oklahoma the optimum planting date for winter wheat used for grain only is October 1-15. (OSU Circular E-831, 1984). Every week that planting is delayed means a resulting decrease in grain yield potential. Failure to achieve the desired plant population will result in three different losses; cost of replanting (which frequently includes one or more cultivations), reduced forage production for grazing animals, and reduced grain yield.

Wheat producers in Oklahoma have been increasing their seeding rates for more than 20 years to achieve adequate stands. This has been necessitated by two factors: increased harvest index of semidwarf wheat cultivars compared to standard height varieties, which requires increased plant populations to optimize production; and increased difficulty in obtaining an adequate stand due to shorter coleoptiles of semidwarf wheats, which requires shallower planting depths than standard height varieties. The former is a positive response to semidwarf varieties' higher yielding capacity, however, the latter has compounded the problem resulting in an even greater trend toward increased plant populations.

The purpose of this study was to define and quantify the problem of wheat stand establishment by interviewing producers as they planted their crop, gathering all pertinent information about stand establishment practices.

The objectives of this study were to:

1. Evaluate wheat producer stand establishment and contrast results with predicted values based upon indicated seeding rates.
2. Identify factors contributing to success or failure in obtaining quality stands.

CHAPTER II

LITERATURE REVIEW

Many factors interact in wheat stand establishment, but they may be broadly classified as soil factors (temperature, moisture, soil type, tilth, surface mulch and residue); equipment factors (seed bed preparation, seeding depth and rate, planter condition and calibration); or seed factors (size, protein, vigor, and coleoptile length).

Several of the soil factors interact with each other. Obviously soil temperature and air temperature are highly correlated, and increasing soil and air temperature increases evaporation resulting in decreased soil moisture. The amount of evaporation will be influenced by surface mulch and residue and by soil type. Less obvious, but equally important,is the observation by Lindstrom et al. (1976) that critical water potential for germination increases (wetter soil) as soil temperature increases, which means that as seed zone temperature is lowered, wheat germinates and emerges in increasingly drier soil.

Soil type interacts with moisture and temperature because heavier clay type soils are extremely prone to form emergence restricting crusts after rain events during warm, early sowing periods. Also, it is more difficult to prepare a firm seedbed in light (sandy) soils than in soils with higher clay content.

Soil surface mulch (residue) acts as a buffer to soil temperature changes. A good mulch may be able to reduce maximum afternoon soil temperature by 13% (Tripathi et al., 1985). Residue mulch is a proven moisture conserver and will lessen the effects of crusting in heavier soils. In contrast, Hadas and Stibbe (1976) found that dry, pulverized soil mulch produced a stronger emergence-restricting crust after rain than did a coarser, cloddy soil in a clean-till system.

The first equipment factor is seedbed preparation which is also influenced by soil factors. Seedbed preparation is critical in maintaining uniform seed-soil contact for good germination, limiting evaporation, and providing uniform firmness so uniform seeding depth can be obtained (Bhatt & Qualset, 1976). Singh and Gill (1972) reported that seedlings of dwarf wheats emerged later from depths below 4 cm than shallower plantings and lacked the required seedling vigor for survival. Also the delay was more apparent at 30 and 35° C than at 20 or 25° C.

Condition of planting machinery and equipment options for the planter (type of opener, type of press wheel, etc.) are critical in stand establishment. Wilkins et al. (1983)

tested six different row openers in limited moisture conditions and found significant differences in emergence, with a modified deep furrow knife opener achieving better emergence than other types of openers from depths greater than 5 cm. Hinkle (1989) in his emergence after rainfall study, found 75 mm wide flat press wheels, in combination with reduced tillage, significantly increased emergence when compared to V shaped press wheels. Hinkle also found that as much as 15 mm more soil was moved into the V shaped furrow by rain than in the flat furrow.

Seeding rate is affected by planting machinery calibration and condition, and seed size. Seed size may be influenced by varietal and year to year variation. Seed size and seed protein are also closely related and both are important in stand establishment. Larger seeds within a genotype have long been observed to produce larger, more vigorous seedlings (Ries and Everson, 1973). However, they also found that the best relationship was between milligrams of protein per seed and seedling weight. Large seeds produced larger seedlings because they contained more protein, or a factor associated with protein, and seedling vigor was otherwise quite independent of genotype.

Coleoptile length is an extensively studied stand establishment component, owing to the introduction of semi-dwarf wheats. Correlation coefficients of 0.805 to 0.98 have been observed for coleoptile length to mature plant height (Feather et al., 1968 and Fick and Qualset, 1976). For most consistent stand establishment the depth of seeding should not exceed the potential coleoptile length for the variety and planting conditions (Feather et al., 1968).

The interaction of soil temperature, coleoptile length and seeding depth has been studied by several researchers. Sunderman (1964) reported significant differences in coleoptile elongation among wheat varieties grown in vermiculite at 15 and 29° C. The average increase in coleoptile length of varieties grown at 15° compared to that of varieties grown at 29° was 47 mm. He also reported significant differences in emergence percent and coleoptile length of wheat varieties sown at three depths of planting in the field at Aberdeen, Idaho. All varieties tested showed a significant increase in coleoptile length at a 12.5 cm sowing depth compared with those sown at 7.5 and 10 cm when the average daily temperature was 13° C. A similar relationship existed between 5, 7.5, and 10 cm depths of planting when the daily minimum and maximum temperature was 16.7 and 27.2° C, respectively (Sunderman, 1964).

Bhatt & Qualset (1976) reported on a study of 18 wheat genotypes at three temperatures. They found coleoptile length, on average, to be 10.16 mm shorter when grown at 32° C compared to wheat grown at 21° C. Burleigh et al. (1962), in their study of varietal differences in emergence as influenced by temperature and seeding depth, concluded that high temperature combined with increased depth of planting can greatly reduce emergence rate and total stand of wheat.

The vast majority of the previous research was conducted in the Pacific N.W., Canada, and abroad. It is difficult to assess the applicability to Oklahoma winter wheat production given the differences in climate, geography, and varieties grown. Some casual observations led this researcher to conclude that Oklahoma producers were not obtaining plant populations expected or representative of the seeding rates being used. Therefore, a field survey of wheat producers was conducted to quantify stand establishment.

CHAPTER III

METHODS AND MATERIALS

This study was set up as a random field survey of wheat producers as they planted their 1992 and 1993 crops. Randomness was achieved by going to a county where that county's extension agriculture agent indicated planting was in progress. The counties were chosen on the basis of availability of enough producers planting on the same day to justify the researcher's time and milage (table 1). The county agent and this researcher drove through the county and visited with each producer encountered who was planting. After explaining the survey to the producer, their responses were recorded if they were willing to participate. Figures 1 and 2 illustrate the survey forms used. Conditions observed included soil type, soil moisture, surface residue and tilth. Tillage information included type of tillage prior to seeding, how many hours prior to seeding the final tillage was done, depth of operation, and whether smoothing harrows were included in this operation. Planter information requested included brand of planter, row spacing, feed type (flute, double run, or air), opener type (single disc, double disc, or hoe), drag chains trailing opener, depth gauge in use, shape and type of press wheel, kind and amount of fertilizer banded with seed, desired seeding depth, desired seeding rate, wheat variety, whether seed was purchased or raised on farm, and whether seed had been cleaned and treated with fungicide. All of this information was recorded as the producer reported it. None of these responses were actually measured or tested during this visit in 1992. However, cultivation depth was measured in 1993, using a 1 cm steel rod pushed into the soil by hand until first resistance or firmness was encountered.

A small seed sample (100 g) was obtained from the producer's planter seed box for a laboratory germination test and for one thousand seed weight. Also, seeding rate was measured by removing three seed drop tubes from the openers and attaching collection bags and planting a measured 30.4 meter distance.

Ten to twenty days after the field was planted, I returned to the same area of the field and counted the actual stand (emergence) at six random locations. The number of plants that had emerged in one meter of drill row were counted; six random plants were carefully dug up in each meter of drill row; and the effective depth of seeding was measured i.e. distance from seed remnant to soil surface. For fields receiving rainfall post-planting pre-stand count, a portion of this depth would be attributed to soil moved by the rain. However, for the purposes of this study, this distance will be refered to as actual planting depth. One coleoptile was measured per meter of drill row; measuring from the seed to the tip of the coleoptile. Any time a skip was encountered in the meter of row i.e. any area of 10 cm or more with no emerged plants, the surface soil was carefully removed in an effort to determine the cause. This information was recorded as YAL's (yellow accordion leaves), seedlings which were planted too deep for the coleoptile to emerge through the soil surface. This results in the first true leaf emerging below the soil surface and being trapped forming yellow wrinkled leaves. Whether or not rain had been received in the interval between planting and emergence was also recorded. It was also noted whether the rain had resulted in a noticeable crust.

Laboratory tests included thousand seed weights, obtained using an electronic counter (Agricultural Specialty Co. Inc.) to count out 1000 seeds which were then weighed. If the seed was trashy, only trash pieces large enough to affect the counter operation were removed since this seed was being planted in this condition and the sample's condition would have been changed if it was cleaned. The three bags of seed collected from the 30.4 meter long planting in the field were weighed and transformed to kg/ha. Using thousand-seed weights, grams of seed/30.4 meter of drill row were converted to seeds per meter of drill row. When producers were unwilling or unable to allow seed collection from the measured 30.4 meter pattern, the seeds per meter were estimated by comparing the average seed size (grams/thousand seed) of seed box sample to normal seed size for wheat (27.25 grams/thousand seed or 1,000,000 seed/bu.). Percent emergence was calculated as plants/m divided by live seeds/m planted. Germination (% live seeds) was determined by wet blotter germination test (AOSA procedure) with one exception; broken or damaged seed was not removed from the sample to be tested because the seed was being planted in this condition.

Statistical analyses performed included analysis of variance, regression and correlation analysis, and variance components estimation procedures. Percent stand was analyzed by regression and correlation on each of the following; actual planting depth, seed size, seed size when planting depth was deeper than 3.5 cm, standard deviation of planting depth, cultivation depth, and T test values. Regression and correlation analysis were run for standard deviation of planting depth on cultivation depth. Regression and correlation were also run for standard deviation of planting depth on actual planting depth. A T test was performed on each producer's accuracy of obtaining desired planting depth [(desired depth - actual depth) divided by standard error]. Actual planting depth was considered to be the mean of each producers measured seeding depths. A variance components estimation procedure (SAS) was performed on producers planting depths to determine if variance of planting depths was within rows, across rows, or both. The standard deviation of planting depth data was entered as a set and the standard deviation of that set was determined, to set bounds for allowable deviation of planting depth.

RESULTS AND DISCUSSION

CHAPTER IV

The average percent emergence for 48 fields surveyed in the fall of 1992 was 57.2% and 57.4% for 59 fields surveyed in the fall of 1993, indicating no year to year variation (P=.05). The time frame of the survey (9 September to 1 November) corresponded with 74% of the state's 1992 crop being planted and 84% of the 1993 crop being planted (Oklahoma Agricultural Statistics Service). Fig. 3 shows that only one out of ten fields achieved 80% or better emergence in 1992 and only 13.6% achieved the same level in 1993. Another 16.7% of 1992 fields achieved between 70% and 79.9% emergence, while 11.8% of 1993 fields reached this same emergence level. Emergence was calculated on the basis of number of viable seed planted per meter of row. Stated another way, in more than 70% of the fields surveyed less than 7 plants emerged for every 10 viable seeds planted. Although there was not a response line on the survey form for what the producer expected his emergence to be, casual conversations with producers indicated most expected at least 70 to 75% of their seed to emerge. When adjusted for overall average germination of 90% in this study, this would correspond to 78 to 83% of viable seed expected to emerge. Also included in Fig. 3 is an expected emergence bar representing a standard distribution "F curve" superimposed over the data. A "F" distribution is a skewed distribution with all of the rejection region in one tail. This would estimate a normal distribution of percent emergence with 80% emergence as the target goal (peak of curve) and less than 60% emergence as the rejection region, i.e. the long tail of a "F" distribution ($p = .1$). It is acknowledged that the percent emergence in some of these wheat fields may have improved after the emergence count was completed if favorable rainfall was received, however, these numbers clearly show stands obtained were less than expected.

Only seven of 114 total seed samples germinated less than 85%. While this is not a major factor, it does highlight the need to test seed germination before planting so that seeding rates can be adjusted accordingly.

To assess seeding rate accuracy, a plus or minus 15% window of accuracy was established around each producer's desired (reported) seeding rate. If the actual seeding rate (kg/ha) was within the window, the producer met his desired rate. In 1992 and 1993, 50% and 57% of fields surveyed respectively, were outside this window of accuracy. Again, casual conversations with producers indicated the majority did not calibrate their planter, but rather set it by the manufacturer's chart. These results would indicate a need for producers to calibrate their planter, at least to check the manufacturer's chart as compared to the amount of feed mechanism wear of their particular planter and seed size. While these are important factors in achieving the desired stand, they did not enter into calculations of emergence in this study because emergence was based on live seed planted, not suggested (desired) seeding rate.

Seed size distribution is shown in a bar graph in Fig. 4. One notable observation was that seedlots smaller (lighter) than 20 grams per one thousand seed resulted in lower emergence (46%) as compared to heavier seed lots (60%).

Other researchers (Ries and Everson, 1973) have observed high correlations between seed size (or protein) and seedling emergence (or vigor). Fig. 5 shows that correlation between percent emergence and seed size was small (Pearson correlation coefficient = 0.28), but significant (OSL = 0.004). Correlation between percent emergence and seed size when planting depth was greater than 3.5 cm. (Fig. 6) was similar (Pearson correlation coefficient = 0.25) and significant (OSL = 0.047).

I feel that most of the difference between these results and other published data comes from an unknown amount of variation resulting from extremely varied weather patterns in the western half of Oklahoma during the two survey years. In 1992, most wheat producing areas of the state were wetter than normal through the summer, delaying field work and seedbed preparation until early September. Very little precipitation was recorded in most of the area from then until late November when the weather returned to a wetter (too wet) pattern for the winter. In 1993, the summer precipitation was normal or drier in most areas. The September through November planting period was marked by spotty rainfall, with some small areas not receiving any.

The soil and air temperatures during the fall planting period of 1992 were normal or warmer, which may have shortened maximum coleoptile extension. In the fall of 1993, temperatures tended to be normal or cooler (Oklahoma Climatological Survey). Also, coleoptile length increased in cooler soil (later planting dates) as expected based upon previous data (OSU extension bulletin PT93-13), with a few observations approaching 7 cm compared to the average coleoptile length (3.9 cm) recorded in this survey. Therefore better emergence could be expected from deeper planting depths in the last half of the planting season due to cooler soil temperatures.

Percent emergence as affected by actual planting depth was examined and no relationship was found (Pearson correlation coefficient = 0.023; OSL = 0.81). However, planting depths were only determined on emerged plants, while visual observations at the time stand counts were taken lead me to strongly believe significant amounts of seed were placed too deep to emerge in some fields and too shallow to germinate without rain in other fields. A few fields were observed to have both conditions. Shallow seedings were observed as ungerminated seeds in the top 1.5 cm of soil (including some on the soil surface) which may have produced plants if favorable rain was received, and germinated but not emerged (GBNE) seedlings in the top 2.5 cm of soil resulting when rainfall was received post planting but before emergence counts were conducted. These GBNE seedlings were likely to have produced plants if moisture in the surface layer was adequate, but they are vulnerable to desication if the rainfall was minimal. Ten or more of these ungerminated plus GBNE observations per meter of drill row were recorded in 47% of 74 fields surveyed from the time for which these observations were recorded. Deep seedings were observed as yellow, wrinkled, accordion-like leaves (YAL) resulting from seed placement deeper than the maximum length of the coleoptile which meant the first true leaf of the plant started growing below the soil surface and wasn't able to emerge. Ten or more of these observations per meter of drill row were recorded in 23% of 74 fields surveyed.

Variation of planting depth was analyzed from several different perspectives. To assess how close the actual planting depth was to the producer's desired planting depth, a T test of desired depth minus actual depth divided by standard error was conducted. In 1992, 73% of the fields surveyed were planted at a depth significantly different ($p = .1$) than the desired planting depth, while in 1993, 83% were significantly different. The overall trend was negative (deeper than desired) with 68% deeper than desired and 11% shallower than desired (Fig. 7). Casual conversations with producers about planting depth have led me to believe the majority don't know how deep they are planting, but instead set the planter openers "where it feels right".

The relationship between percent emergence and cultivation depth was examined for the 1993 year only since no measurements of tillage depth were recorded in the 1992 survey. Even though 44% of fields were cultivated deeper than 8 cm (1993) and deep tillage was expected to make seeding depth more difficult to control, correlation between percent emergence and cultivation depth was not significant (OSL = 0.389; Pearson correlation coefficient = - 0.11). A slight relationship between standard deviation of planting depth and cultivation depth (Pearson correlation coefficient = 0.25;OSL = 0.056) was observed (Fig. 8). No relation (OSL = 0.312) between percent emergence and standard deviation of planting depth was found. Differences between these findings and those of previously published studies is due mostly to weather variation and lack of control plots in a random survey.

Actual planting depth data were analyzed to determine what portion of variance was within rows and what portion was across rows (variance components estimation procedure, SAS). For 1992, variation within rows (OSL < 0.005), and across rows (OSL < 0.01) were both significant. In 1993, the only significant variation was within rows (OSL <0.005).

In an effort to further quantify standard deviation of planting depth, the producer's planting depth standard deviations were entered as a set of data and the standard deviation of that set was obtained. This tells us how much deviation of planting depth could be considered normal. That deviation was found to be 0.31 cm which was doubled (0.62 cm) to give two standard deviations away from the mean, i.e., the normal amount of deviation from mean planting depth that be might expected. Only 9.4% of fields surveyed were within the normal deviation range (+ or - two standard deviations). This indicates the variation of planting depth in most fields was very high and further study is needed to help identify and correct the problem.

Thirty percent of planters encountered in this survey were equiped with depth gauges on individual row openers. Regression and correlation analysis between standard deviation of planting depth and actual planting depth for these planters was conducted (with samples not having sufficient moisture for germination removed) and no relationship (OSL = 0.13) was found (Fig. 9). When the same procedure was conducted for planters without depth gauges (Fig. 10), a significant relationship was found (Pearson correlation coefficient = 0.35; OSL = 0.005). This means that depth gauges removed enough variation of planting depth to change the relationship significance level (OSL = 0.005 versus OSL = 0.13).

Planting depth plus or minus the producers variation of planting depth was examined to determine how many producers were planting too deep or too shallow. For instance, if a producer was planting 4.5 cm deep to be in moist soil, with a variance of 1.5 cm, roughly 30% to 40% of the seed would be too deep for maximum coleoptile extension (approximately 5 cm for most semidwarf wheat) to reach the soil surface. Variation is defined as the average distance of an observation away from the mean of the sample, i.e. half of the observations would be less than 1.5 cm from the mean and half of the observations would be further away from the mean than 1.5 cm. In theory, half of the observations would be shallower than the mean and half deeper. Therefore, 60% to 80% of the deeper than mean seedings (30% to 40% of total) would be deeper than 5 cm. In the context of planting depth + or - variation of planting depth, 16% were too shallow and 12% were too deep to expect good emergence in accordance with moisture and temperature conditions.

In conjunction with the preceding observations, YAL's were recorded starting midway through 1992's survey in an effort to find out what was happening in fields that had skips (blank spaces) in the seed row. These observations are generally a sure indication that at least a portion of the seeds have been planted too deep for the coleoptile to grow enough to reach the soil surface. Ten or more YALs per meter of row were observed in 23% of the 74 fields surveyed (latter half of 1992 survey and all of 1993) for which this observation was recorded.

In further effort to analyze the variability and poor stands in some fields, the data were reexamined and coupled with the researcher's visual appraisals of each field on the basis of this researcher's 20 years experience raising winter wheat in west-central Oklahoma. First, fields were rated for sufficient moisture to expect good germination and emergence and 14% were found to be too dry at planting to expect good emergence without rain. This determination was based on conditions in the field on the day of planting and the day of emergence count. Of course, the producer must make this determination on the day of planting only without the benefit of hindsight this researcher had. In general, these fields were planted deeper than 4 cm in an effort to put the seed into moisture and it is questionable whether seed not deep enough to reach moisture at planting would be able to emerge before a soil crust would form following a rain. Dusting in (planting 1-2 cm deep in dry soil to be germinated by the next rainfall) may have been a better option in some of these fields.

Four percent of the fields had emergence preventing crusts due to rainfall in the interval between planting and emergence. As much as another 14% of fields had crusts that restricted emergence by a noticeable but unknown amount, based on the knowledge that any soil crust has the potential to limit emergence. This was observed as ten or more YAL's per meter of drill row with coleoptile length less than 5 cm.

The following discussion covers observations that were not of sufficient quantity or nature for meaningful statistical analysis but appear noteworthy based on this researcher's production experience and scientific training. Many different brands and types of planters, row openers, feed types, etc., were observed and no noticeable advantage was seen for one over another. In general, the operator was the most important planter factor; a good operator could get excellent emergence with less than ideal equipment and a less observant operator could have trouble with state of the art equipment. One exception to this rule was depth gauges. In all cases observed, depth gauges improved emergence and lessened standard deviation of planting depth (SD = 0.77 cm) as compared to planters without depth gauges (SD = 1.01 cm). The smallest observed variance in planting depth (SD = 0.14 cm) was obtained by two John Deere planters using a depth gauge that mounted immediately beside a double disc opener. Depth gauges mounted behind the openers were not as effective as those that mounted beside the opener.

One operator factor worth noting was speed of travel while planting. A few producers appeared to be traveling too fast to allow the row openers to make good soil contact, i.e. the openers seemed to bounce due to excessive speed.

Cultivation equipment followed the same trend as planting equipment; that is, being more dependent on the operator than on the brand or type of equipment. Two notable exceptions are mulch treaders and cultipackers, which produced noticeably firmer seedbeds and better emergence (63%) compared to the overall average (57%). This difference is even larger since the cultipackers and mulch treaders were working in sandier, lighter textured soils than average. Also worth noting, 11% of fields appeared to have lost too much moisture for germination to occur due to excessive cultivation prior to seeding and/or excessive time between cultivation and seeding, as evidenced by 35.5% average emergence in those fields.

Other data recorded but not mentioned (soil type, surface residue, fertilizer with seed, etc.) were used to aid this researcher in summarizing data and explaining data points that did not fit trends and thus are not major factors in this study. Data of this type with sufficient observations for summarization are presented in figures 11 and 12.

In summary, wheat stands achieved in Oklahoma during 1992 and 1993 were much lower (57% of live seed planted) than was expected and/or desired (80% of live seed planted). Two major causal factors of this problem have been identified.

The first factor, which can be improved by both researchers and producers, is planting depth relative to coleoptile length. Large improvements in percent emergence can be gained through improved accuracy of obtaining desired planting depths as evidenced by more than 70% of fields surveyed being planted at depths significantly different from the depth desired. The following are areas which influence planting depth and need further research investigation and extension education: 1.) cultivation depth; 2.) setting planting depth, including depth gauges; 3.) wider press wheels individually attached rather than gang attachment; and 4.) planting speed.

It is also suggested that future research should be done in the area of selection for longer coleoptiles for semidwarf wheat. Moisture sufficient for germination and emergence frequently seems to be two to four centimeters deeper than the coleoptile's maximum possible extension. Whether this is accomplished by traditional breeding using wild germplasm or through biotechnology utilizing non-wheat genes, this seems an attainable and worthwhile goal.

Further evaluation of the relationship between soil temperature and coleoptile extension should be made with possible selection efforts to remove coleoptile growth restriction at high temperatures. Deep planting into warm, dry soils early in the season will continue to be a popular scenario for Oklahoma wheat producers desiring early fall grazing for livestock.

The second factor is weather and climatic conditions in Oklahoma, over which there is little control. During the survey years, most production areas were plagued with small pockets of drought and very unpredictable small rain showers during fall seeding times, which aided emergence in a few fields and hindered it in many others. This also led to some producers planting in fields that were marginally moist when they were concerned there wouldn't be any more rain during the planting season. Although this study presents no solution to the weather factor, more uniform planting even into less than desireable conditions should enhance chances for emergence when rainfall does occur.

This study has shown large variability in planting depth across Oklahoma. It has also suggested several areas of research to help correct the problem which are well within the capabilities of current technology.

REFERENCES CITED

Bhatt. G.M., and C.O. Qualset. 1976 Genotype - environment interactions in wheat: effects of temperature on coleoptile length. Expl. Agric. 12: 17-22.

Burleigh, J.R., R.E. Allan, and O.A. Vogel. 1962. Varietal differences in seedling emergence of winter wheats as influenced by temperature and depth of plants. Agron. J. Vol 56: 195-198.

Cuperus, G., R. Johnston, and others. 1984. Wheat production and pest management in Oklahoma. Cuperus and Johnston Ed. Oklahoma State University Coop. Ext. Circ. E-831.

Feather, J.T., C.O. Qualset, and H.E. Vogt. 1968. Planting depth critical for short statured wheat varieties. Cal. Agric. Vol 22 #9: 12-14.

Fick, G.N., and C.O. Qualset. 1976. Seedling emergence, coleoptile length & plant height relationships in crosses of dwarf and standard height wheats. Euphytica Vol. 25: 679-684.

Hadas, A., and E. Stibbe. 1977. Soil crusting and emergence of wheat seedlings. Agron. J. Vol. 69: 547-550.

Hinkle, S.E. 1989. Winter wheat emergence after 30 minutes simulated rainfall. Transactions of ASAE Vol. 32: 1577-1581.

Lindstrom, M.J., R.I. Papendick, and F.E. Koehler. 1976. A model to predict winter wheat emergence as affected by soil temperature, water potential, and depth of planting. Agron. J. Vol. 68: 137-140.

Oklahoma Climatological Survey, 1993. Oklahoma October monthly summary, pg 3. OCS, University of Oklahoma.

Oklahoma Agricultural Statistics Service, 1993. Oklahoma crop weather summary, Vol. XVI, no. 31, 38.

Ries, S.K., and E.H. Everson. 1973. Protein content and seed size relationships with seedling vigor of wheat cultivars. Agron. J. Vol. 65: 884-886.

Singh, O.S. and K.S. Gill. 1972. Some physiological aspects of effects of kinetin,depth of seeding and soil temp. on seedling establishment and metabolism of dwarf wheats. Indian J. Agric. Sci. Vol. 42 (3) 205-210

Sunderman, D.W. 1964. Seedling emergence of winter wheats and its association with depth of sowing, coleoptile length under various conditions, and plant height. Agron. J. Vol. 56: 23-25.

Thompson, J. D. 1990. Varietal and clipping effects on seasonal forage distribution, grain yield and economic returns for winter wheat utilized as a dual-purpose crop. Masters thesis Chap. 1:1.

Tripathi, R.P., A.K. Singh and R.K. Mishra. 1985. Effect of mulch-induced soil thermal regime on wheat emergence. Field Crops Research, Vol. 10: 305-313.

Wilkins, D.E., G.A. Muilenburg, R.R. Allmaras, and C.E. Johnson. 1983. Grain-drill opener effects on wheat emergence. Transactions of the ASAE. 651-660.

APPENDIXES

APPENDIX A

FIGURES

Fig. 1. 1992 Wheat planting survey form.

1992 WHEAT PLANTING SURVEY

SAMPLE # ________

ROGER STOCKTON
OKLAHOMA STATE UNIVERSITY
STILLWATER, OK

COOPERATOR'S NAME ____________________

LOCATION: COUNTY ____________________

DIRECTIONS FROM LANDMARK: ____________________

____

OBSERVED CONDITIONS:

SOIL TYPE: ____________ SOIL MOISTURE: ____________

SOIL RESIDUE/ORGANIC MATTER:

CLEAN TILL ... NO TILL

1 2 3 4 5 6 7 8 9

TILLAGE AHEAD OF SEEDING:

TYPE: ____________ DEPTH: ____________

HOURS AHEAD OF SEEDING: ____________________

PLANTER INFORMATION:

BRAND: ____________ FEED TYPE: ____________

OPENER TYPE: ____________ DEPTH GAUGE: ____________

PRESS WHEEL: ____________________

FERTILIZER WITH SEED: ____________________

SEED DEPTH DESIRED: ____________ MEASURED: ____________

SEEDING RATE DESIRED: ____________ MEASURED: ____________

WHEAT VARIETY: ____________________

MEASURED STAND: DATE: ____________________

PLANTS PER YARD OF ROW:

1. ____________ 5. ____________

2. ____________ 6. ____________

3. ____________ 7. ____________

4. ____________ 8. ____________

LABRATORY GERMINATION: ____________________

RAIN BETWEEN PLANTING AND EMERGENCE

Fig. 2. 1993 Wheat planting survey form.

1993 WHEAT PLANTING SURVEY

Roger Stockton OSU
562 AG HALL
744-9637

SAMPLE #____________________

Cooperator's Name____

County______________Directions____

____

OBSERVED CONDITIONS: SOIL TYPE____

SOIL MOISTURE____

RESIDUE: CLEAN TILL 1 2 3 4 5 NO TILL

TILTH: MELLOW 1 2 3 4 5 CLODDY

TILLAGE AHEAD OF SEEDING:_______________________WHEN:__________________

HARROWS: Y N DEPTH:____

PLANTER INFO: BRAND:____

SIZE:_____________________ FEED TYPE: FLUTE DR AIR

OPENER TYPE: SD DD HOE DRAGS: Y N DEPTH GAUGE: Y N

PRESS WHEEL:____

FERTILIZER WITH SEED:____

SEED DEPTH: DESIRED_______________________MEASURED_______________________

SEEDING RATE: DESIRED_______________________MEASURED_______________________

WHEAT VARIETY:______________________________PURCHASED: Y N C/T: Y N

MEASURED STAND:______________________________DATE:__________________________

PLANTS PER METER OF ROW AND DEPTH: COLEOPTILE LENGTH YAL'S:

_____ 1.______:______:______:______:______:______: __________ __________

_____ 2.______:______:______:______:______:______: __________ __________

_____ 3.______:______:______:______:______:______: __________ __________

_____ 4.______:______:______:______:______:______: __________ __________

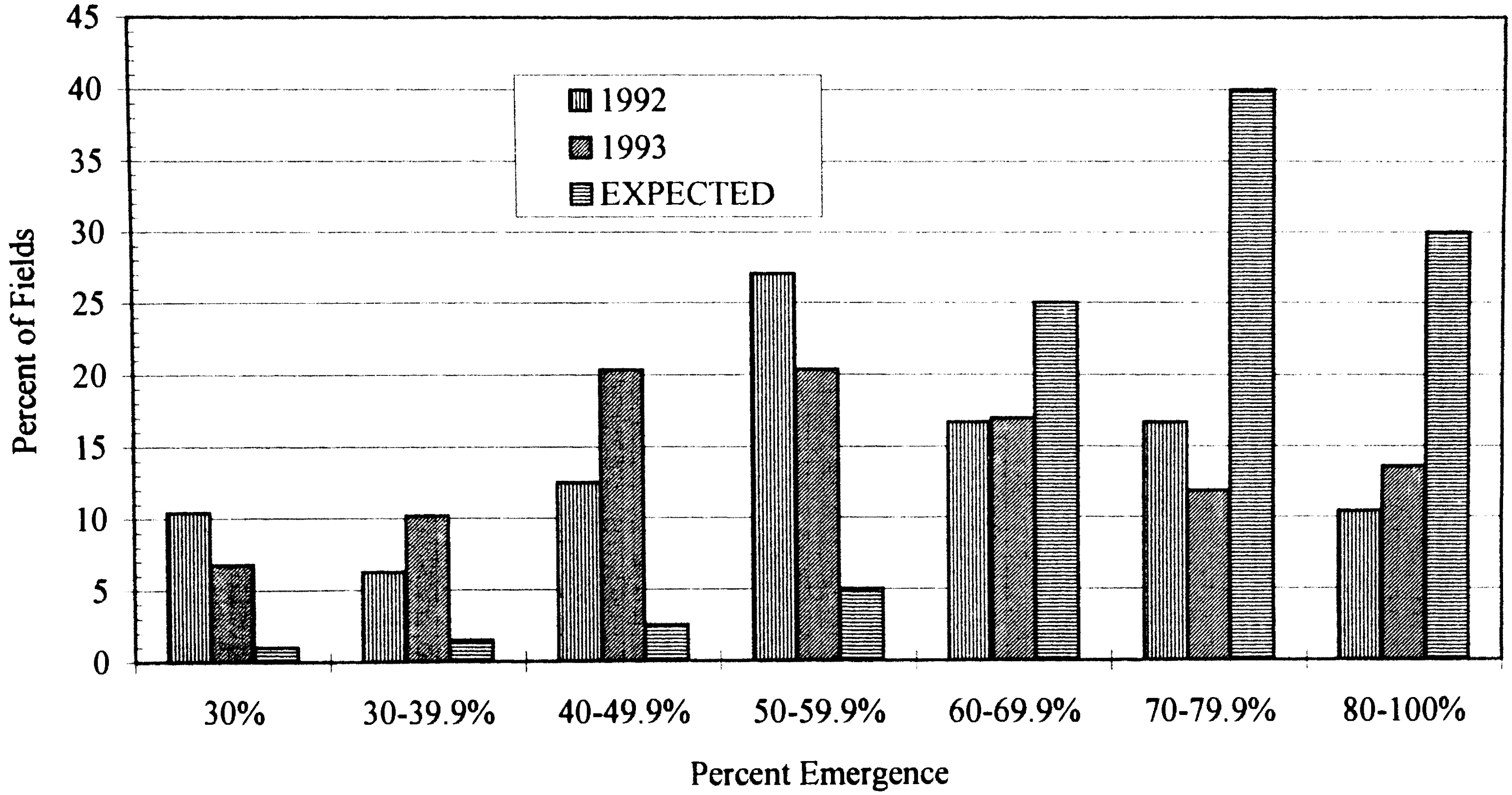
_____ 5.______:______:______:______:______:______: __________ __________

_____ 6.______:______:______:______:______:______: __________ __________

RAIN AFTER PLANTING:__________________________ CRUST: ______________________

LABORATORY GERMINATION:____

Fig. 3. Percent of emergence of wheat by percent of fields and expected emergence †



† Expected Emergence = standard distribution "Fcurve" with 10% in rejection tail (60% emergence)

Fig. 4. Distribution of seed by size and percent emergence

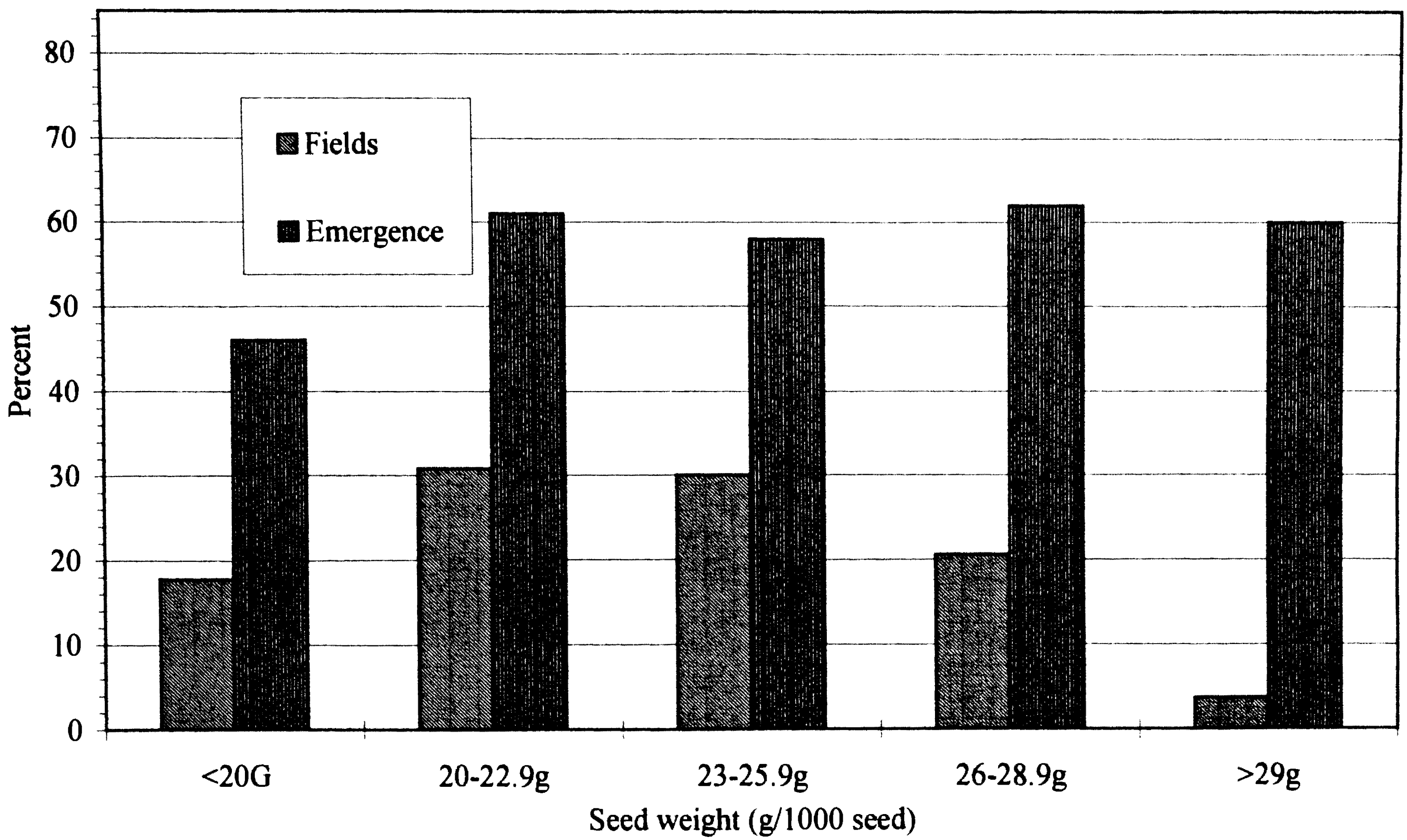


Fig. 5. Regression of seed weight (grams) on % emergence

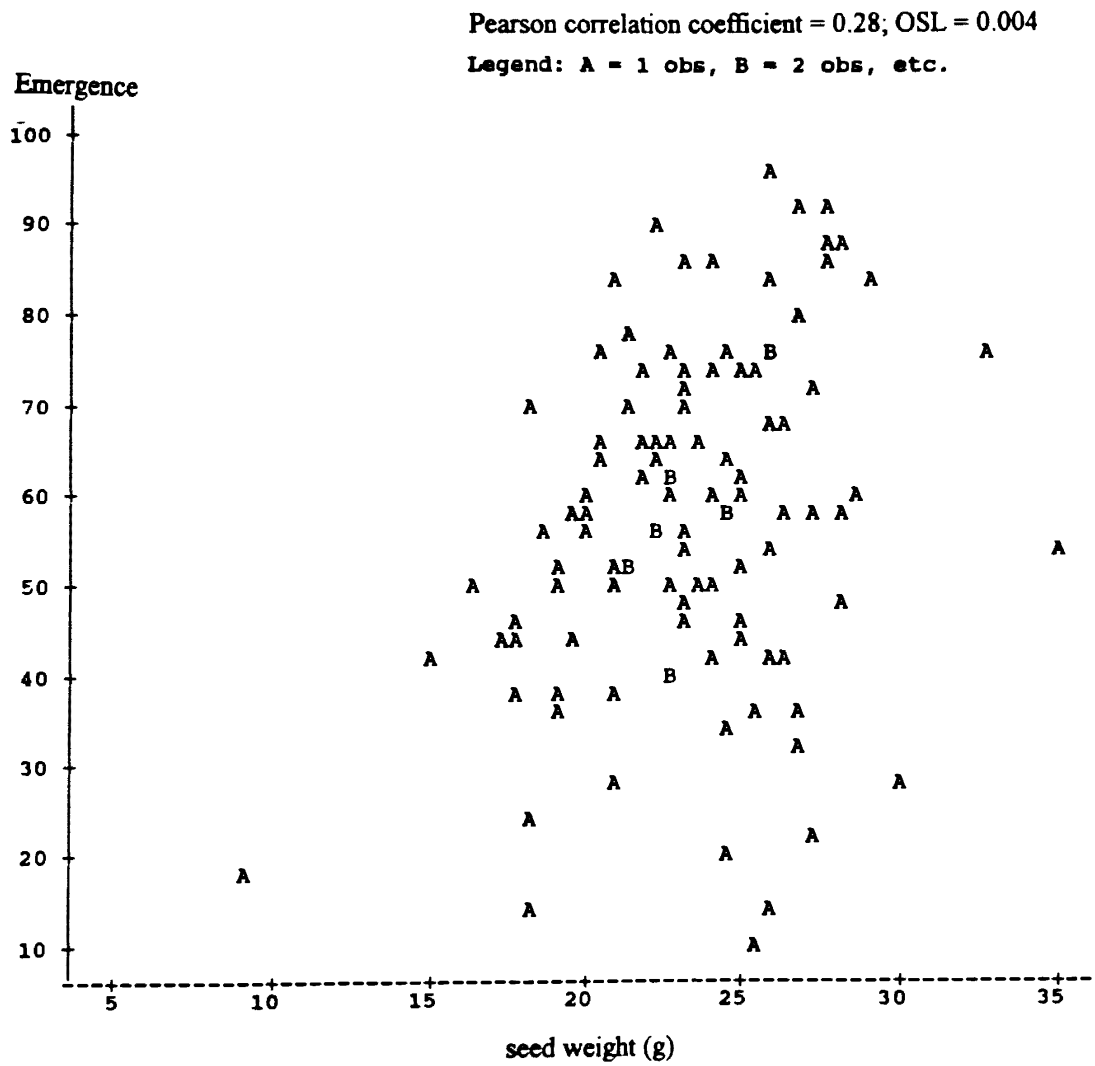


Fig. 6. Regression of seed weight (grams) on % emergence if planting depth > 3.5 cm.

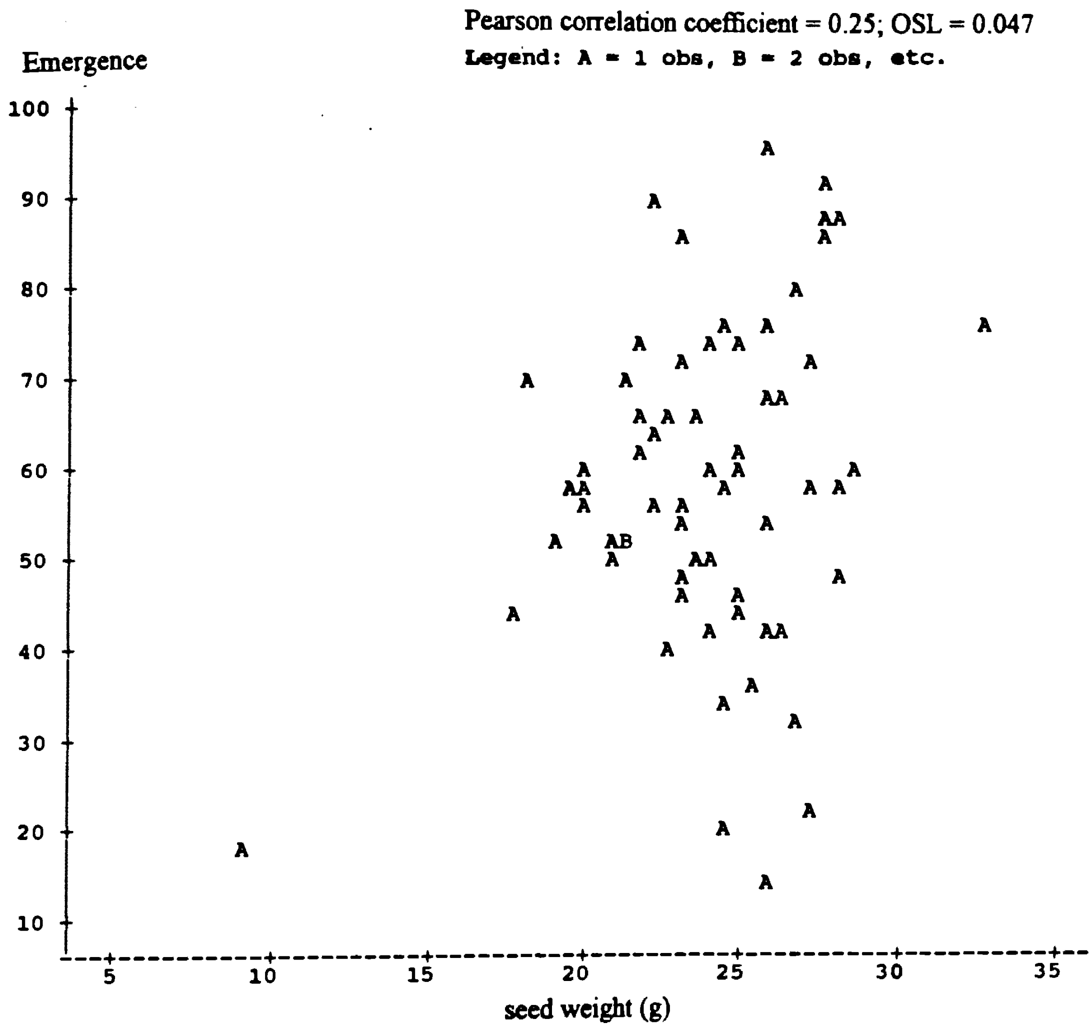


Fig. 7. Deviation of seeding depth from the desired seeding depth regressed against %emergence

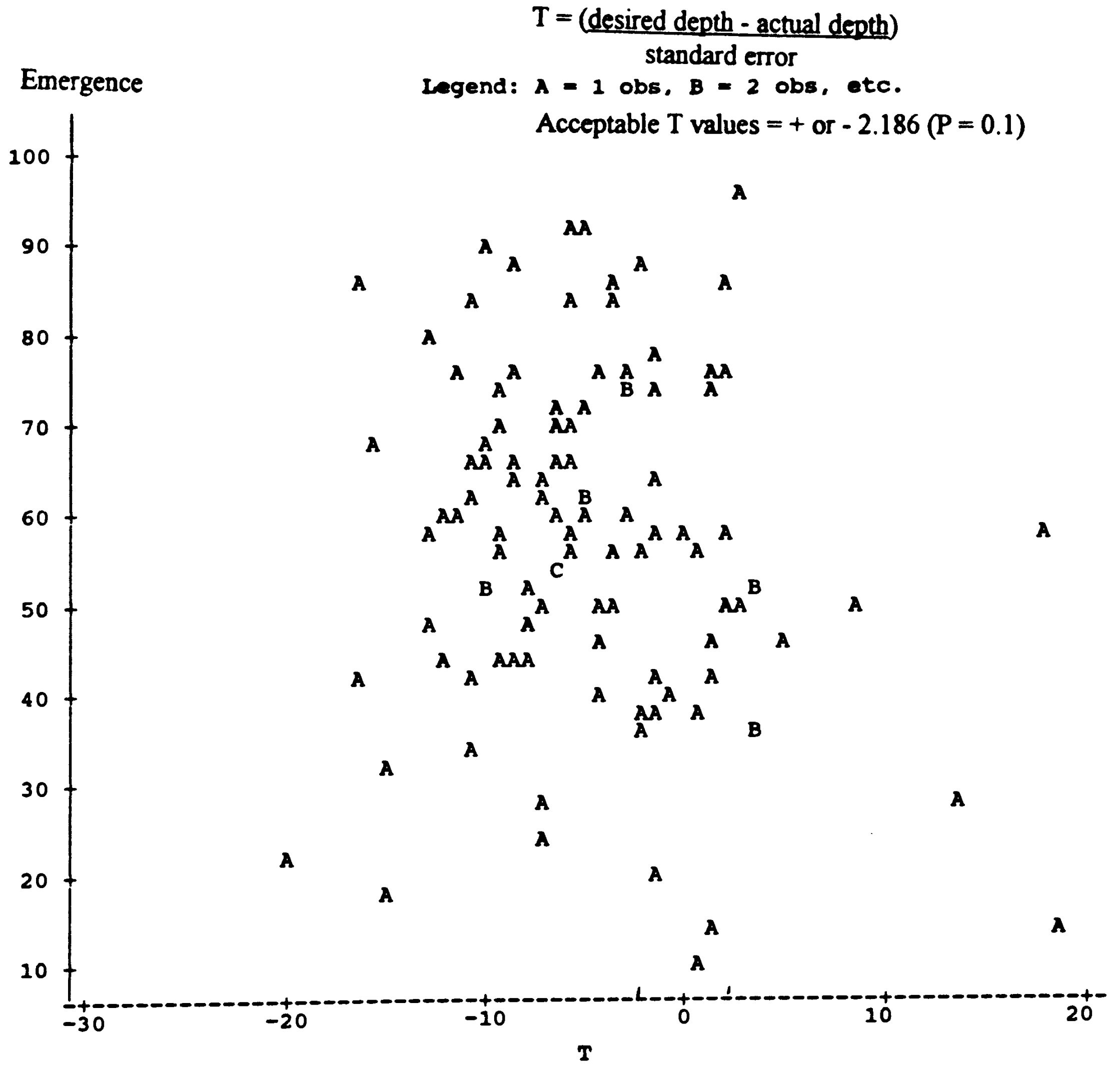


Fig. 8. Regression of cultivation depth on standard deviation of planting depth.

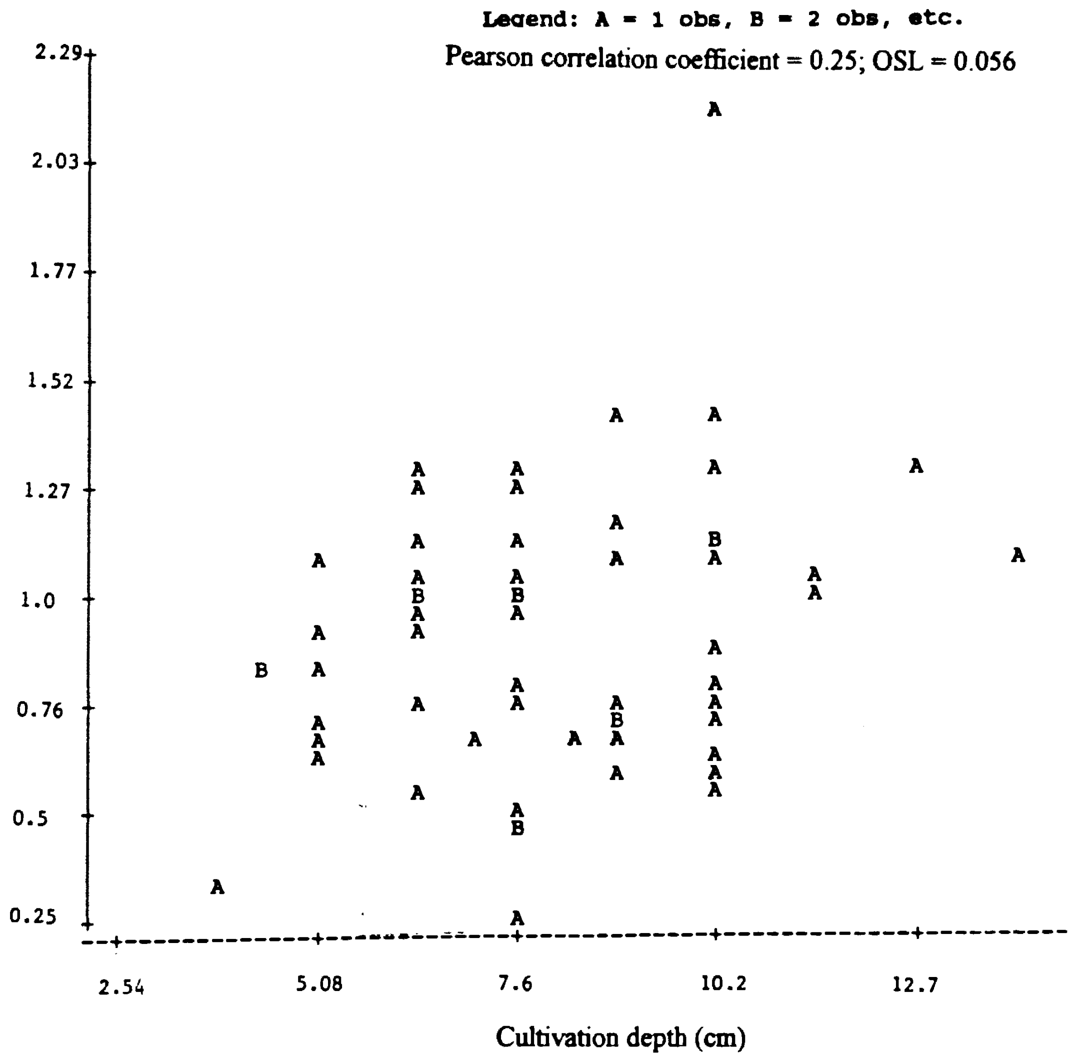


Fig. 9. Regression of actual planting depth on standard deviation of planting depth for planters with depth gauges.

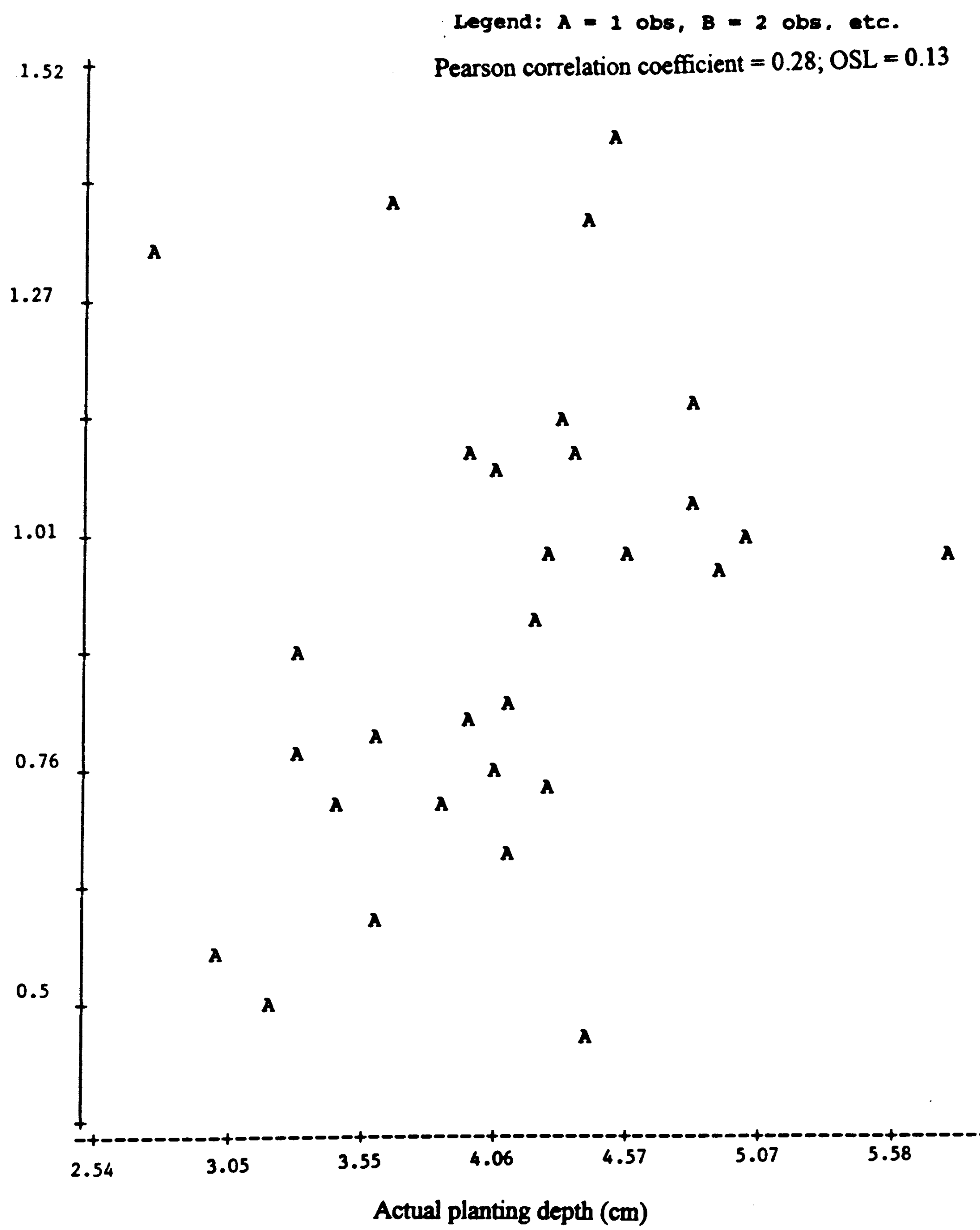


Fig. 10. Regression of actual planting depth on standard deviation of planting depth for plant without depth gauges.

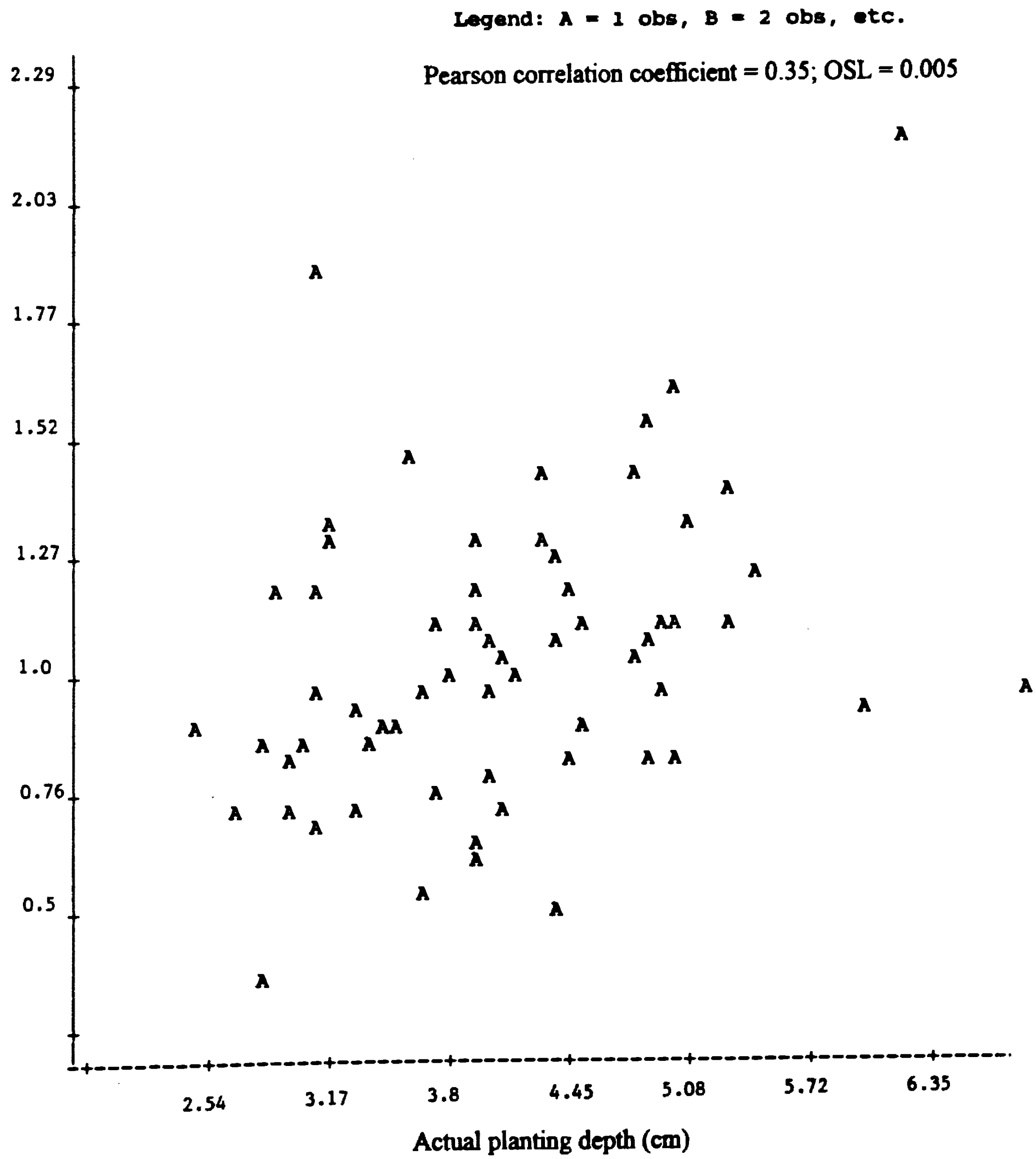


Fig. 11. Seed origin, treatment, and fertilizer

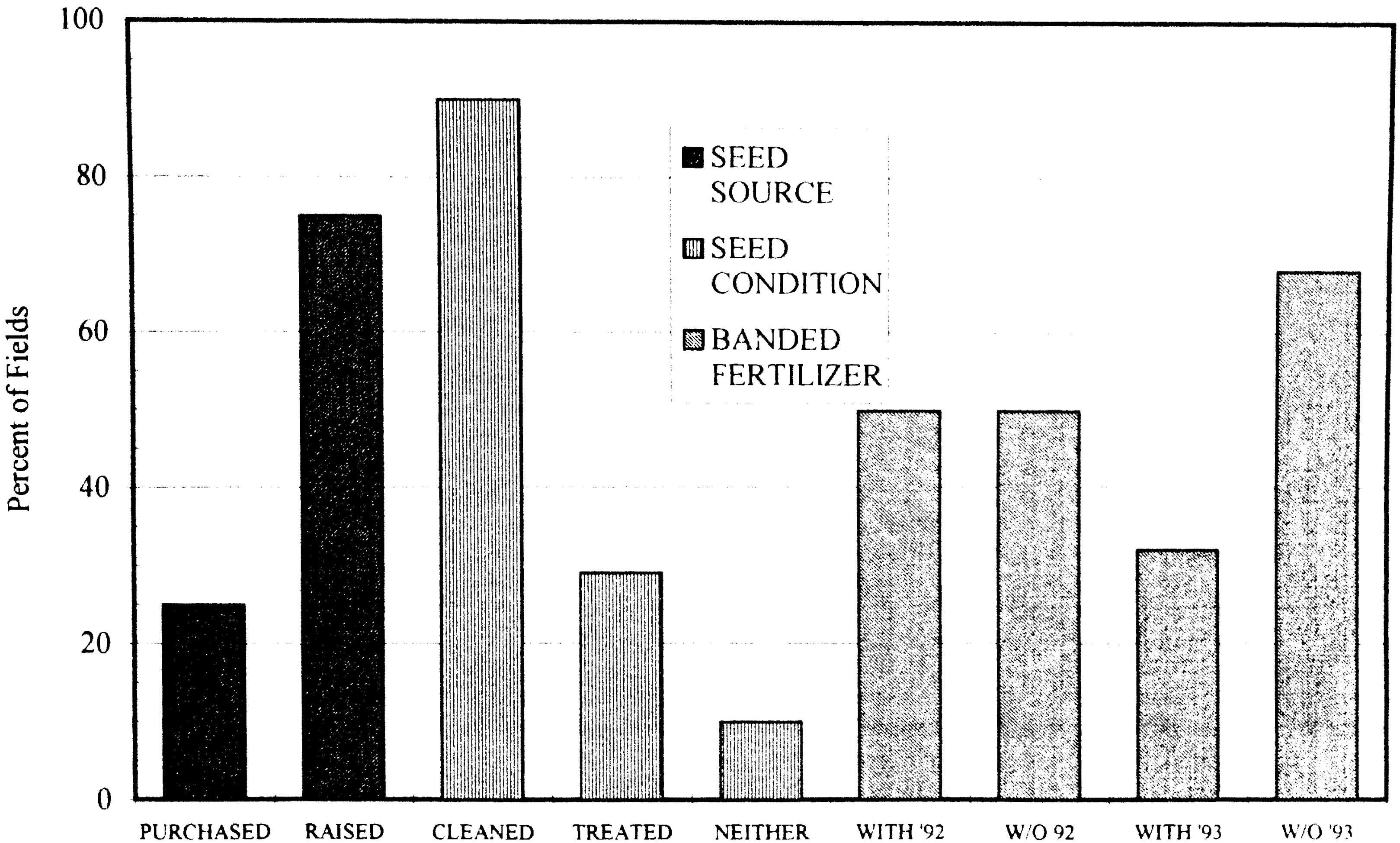
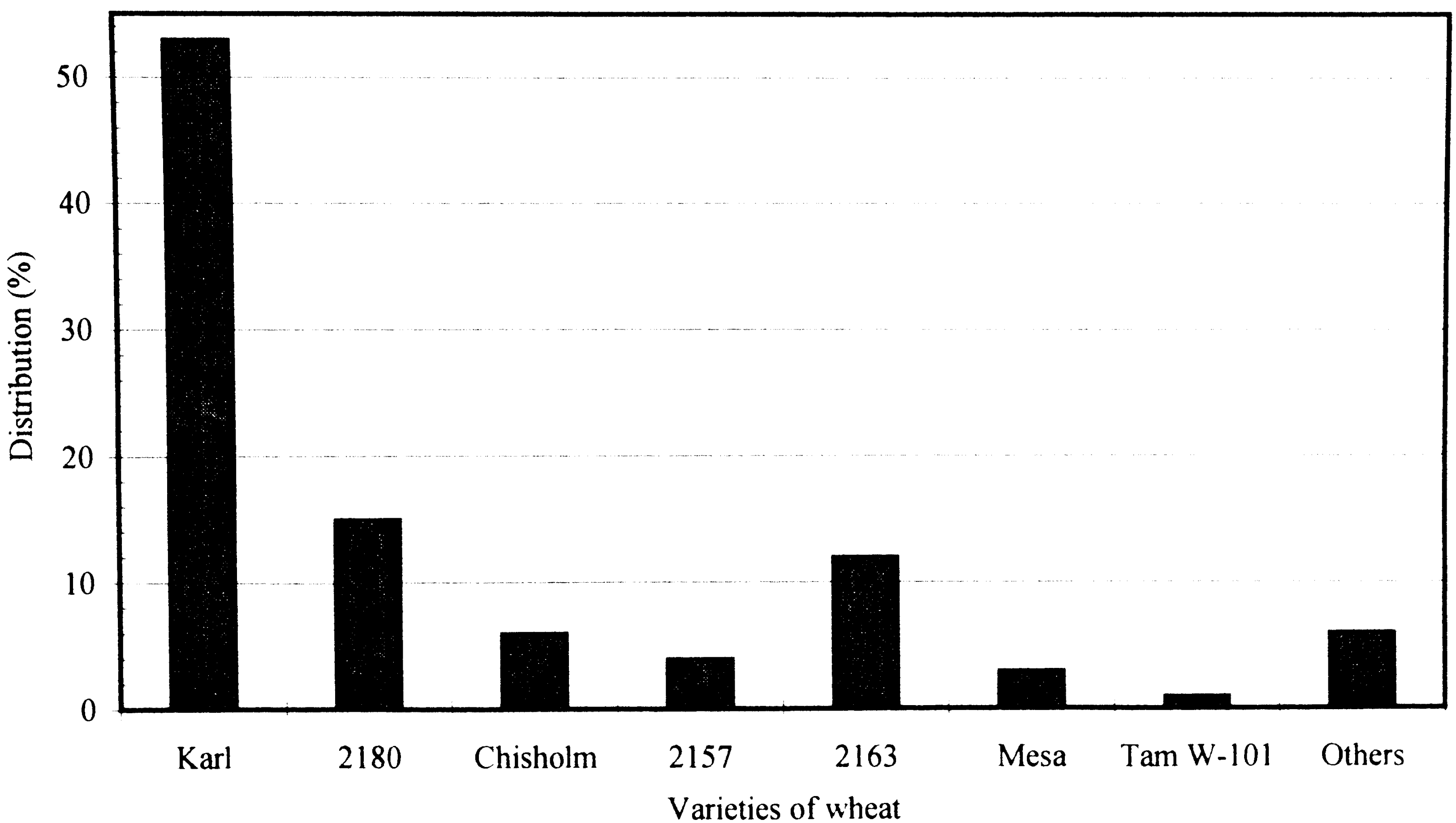


Fig. 12 Distribution of wheat varieties



APPENDIX B

TABLES

TABLE 1. Counties surveyed

Counties	Year	Year
Garfield	92	93
Grant	92	
Alfalfa		93
Custer		93
Washita	92	
Kay	92	93
Grady	92	93
Canadian		93
Kingfisher		93

Legend: Qualitative analysis conducted on fields with stand <70% to determine primary causes of poor stand;

A - soil excessively dry for good germination

B - planted excessively deep

C - planted excessively shallow

D - soil crusted pre-emergence

E - pre-plant cultivation excessively deep

F - excessive pre-plant cultivation

G - excessive residue interfering with opener

H - seedbed firmness preventing adequate opener penetration

I - planting speed of travel excessive

J - soil moved over row by post-planting rain

K - presswheel malfunction

Legend: Producer - sample number

SDV - standard deviation of planting depth

N - number of depths recorded per producer

Desired depth - depth of planting producer desires

Actual depth - measured distance from seed to soil surface

Stand - number of plants/100 live seeds planted

Year - year data recorded

T-test - $\frac{\text{(desired depth - actual depth)}}{\text{standard error}}$

Table 2. Individual producer stand establishment data 1992

Qualitative Analysis	Producer	SDV	N	Desired depth	Actual depth	Stand	Year	T-test
DF	34	0.365	23	1.50	1.439	10.4	92	0.8015
EBJ	45	0.383	36	1.00	1.939	17.4	92	-14.7102
EA	64	0.519	12	1.50	1.667	20.9	92	-1.1147
EB	55	0.317	18	1.00	2.516	21.5	92	-20.2897
D	41	0.479	36	0.75	1.306	23.3	92	-6.9645
AB	57	0.531	30	1.00	2.013	34.1	92	-10.4490
FA	38	0.248	33	1.25	1.088	35.8	92	3.7525
CG	65	0.743	36	1.00	1.225	37.6	92	-1.8170
AC	51	0.326	31	1.00	1.961	42.6	92	-16.4129
AB	46	0.326	36	1.25	1.922	43.5	92	-12.3681
BE	26	0.385	36	3.00	2.681	45.8	92	4.9714
CA	513	0.433	18	1.50	1.922	46.5	92	-4.1349
C	63	0.525	36	1.50	1.250	49.4	92	2.8571
C	35	0.364	36	1.50	0.964	49.7	92	8.8352
AC	24	0.329	36	1.50	1.742	50.5	92	-4.4134
BE	33	0.538	36	1.00	1.733	52.3	92	-8.1747
E	22	0.571	36	2.25	1.880	52.5	92	3.8879
DB	42	0.387	32	1.50	1.944	54.2	92	-6.4900
CA	31	0.475	36	0.75	1.231	54.7	92	-6.0758

Table 2. cont. Individual producer stand establishment data 1992

Qualitative Analysis	Producer	SDV	N	Desired depth	Actual Depth	Stand	Year	T-test
DC	62	0.303	36	1.50	1.608	55.3	92	-2.1386
BC	54	0.645	36	1.00	1.972	56.8	92	-9.0419
C	516	0.388	17	1.75	1.576	58.0	92	1.8490
CD	36	0.51	36	1.25	1.242	58.2	92	0.0941
CA	514	0.28	18	1.00	1.606	58.4	92	-9.1923
BA	47	0.486	36	2.00	2.131	58.7	92	-1.6173
DC	58	0.442	30	1.00	1.943	59.1	92	-11.6856
AB	25	0.467	36	1.50	1.747	59.3	92	-3.1734
C	21	0.477	36	0.75	1.147	60.6	92	-4.9937
CA	69	0.546	36	1.00	1.436	62.3	92	-4.7912
C	59	0.325	36	1.00	1.567	62.8	92	-10.4677
CA	68	0.35	36	0.87	1.292	64.8	92	-7.2343
DB	27	0.437	33	1.00	1.785	65.3	92	-10.3192
C	66	0.355	36	1.00	1.364	66.8	92	-6.1521
B	512	0.551	24	1.00	2.092	67.7	92	-9.7090
F	515	0.396	24	1.00	2.275	68.1	92	-15.7732
	52	0.468	36	1.12	1.550	70.2	92	-5.5128
	518	0.199	24	1.50	1.717	71.7	92	-5.3421
	48	0.445	36	1.75	1.964	74.1	92	-2.8854

Table 2. cont. Individual producer stand establishment data 1992

Qualitative Analysis	Producer	SDV	N	Desired depth	Actual Depth	Stand	Year	T-test
	67	0.445	36	1.25	1.486	74.8	92	-3.1820
	43	0.367	36	1.75	1.658	74.9	92	1.5041
	32	0.313	36	1.50	1.419	75.0	92	1.5527
	519	0.423	12	2.00	1.733	75.0	92	2.1866
	23	0.587	36	1.25	1.416	78.7	92	-1.6968
	53	0.363	36	1.00	1.783	80.4	92	-12.9421
	37	0.288	36	1.00	1.167	83.8	92	-3.4792
	56	0.378	36	2.50	2.355	85.8	92	2.3016
	511	0.33	24	1.50	1.621	87.2	92	-1.7963

Table 3. Individual producer stand establishment data 1993

Qualitative Analysis	Producer	SDV	N	Desired Depth	Actual Depth	Stand	Year	T-test
FA	1056	0.250	12	1.75	1.633	14.1	93	1.6212
A	9189	0.104	18	1.50	1.044	14.5	93	18.6023
A	1058	0.266	17	2.25	1.371	27.5	93	13.6248
CH	9163	0.341	30	0.75	1.193	28.5	93	-6.9550
AF	93010	0.186	11	1.00	1.845	32.1	93	-15.0675
A	9167	0.263	24	1.50	1.617	36.8	93	-2.1794
AC	9302	0.245	18	1.25	1.033	36.9	93	3.7578
DB	9243	0.519	24	1.50	1.442	37.9	93	0.5475
AC	9301	0.315	24	1.25	1.341	37.9	93	-1.4153
AC	9306	0.307	22	1.12	1.154	39.9	93	-0.5195
EI	9174	0.285	24	1.25	1.516	40.2	93	-4.5724
A	1052	0.494	23	1.75	1.578	41.9	93	1.6698
EA	9172	0.416	24	1.00	1.896	42.2	93	-10.5516
DC	9244	0.471	24	1.00	1.112	42.9	93	-1.1649
C	9165	0.331	36	0.75	1.172	43.1	93	-7.6495
AC	9308	0.235	24	1.00	1.429	43.1	93	-8.9432
D	9241	0.339	24	0.75	1.346	43.7	93	-8.6130
AC	9305	0.362	22	1.50	1.390	45.5	93	1.4253
C	9169	0.434	36	1.00	1.567	48.0	93	-7.8387

Table 3. cont. Individual producer stand establishment c

Qualitative Analysis	Producer	SDV	N	Desired Depth	Actual Depth	Stand	Year	T-test
BA	9237	0.453	24	0.50	1.692	48.4	93	-12.8909
BE	9188	0.856	24	1.25	2.446	49.4	93	-6.8448
AC	9304	0.394	24	1.50	1.795	49.8	93	-3.6680
A	9303	0.289	24	1.50	1.362	50.3	93	2.3393
G	9161	0.308	30	1.50	1.307	51.9	93	3.4322
A	9166	0.292	18	1.00	1.678	52.6	93	-9.8511
E	9164	0.433	36	1.00	1.711	52.7	93	-9.8522
EG	9173	0.240	24	1.25	1.550	53.0	93	-6.1237
AC	9307	0.299	24	1.50	1.470	55.3	93	0.4915
DC	9245	0.222	24	1.50	1.171	56.2	93	-3.7735
E	9233	0.511	24	1.00	1.567	56.7	93	-5.4359
G	9176	0.262	24	2.50	1.542	58.0	93	17.9131
E	91810	0.401	24	1.50	1.975	58.2	93	-5.8030
CH	9162	0.374	36	0.50	1.292	58.5	93	-12.7059
C	1054	0.519	24	1.00	1.696	59.7	93	-6.5697
E	91811	0.454	24	0.75	1.908	60.4	93	-12.4956
D	9238	0.283	24	0.75	1.046	62.6	93	-5.1240
C	9168	0.506	24	1.00	1.721	62.7	93	-6.9806
C	1051	0.568	24	0.75	1.771	63.9	93	-8.8061

Table 3. cont. Individual producer stand establishment data 1993

Qualitative Analysis	Producer	SDV	N	Desired Depth	Actual Depth	Stand	Year	T-test
A	9236	0.382	24	1.00	1.442	65.1	93	-5.6685
E	9232	0.396	24	1.00	1.671	66.3	93	-8.3010
J	9177	0.188	18	1.25	1.733	66.4	93	-10.9000
A	9235	0.200	24	1.00	1.262	69.4	93	-6.4177
C	9239	0.433	24	0.75	1.583	69.6	93	-9.4246
	1055	0.443	24	1.50	2.083	71.0	93	-6.4472
	9175	0.431	24	1.50	1.596	73.2	93	-1.0912
	9246	0.384	24	0.50	1.221	73.3	93	-9.1983
	1057	0.272	24	0.75	1.225	75.0	93	-8.5552
	9275	0.396	24	1.25	1.492	75.1	93	-2.9938
	9171	0.413	24	1.50	1.875	76.2	93	-4.4482
	9271	0.444	24	0.50	1.542	76.9	93	-11.4972
	9242	0.283	24	1.00	1.313	84.3	93	-5.4183
	9274	0.219	12	0.75	1.433	84.3	93	-10.8036
	9309	0.138	24	1.00	1.108	86.1	93	-3.8340
	9273	0.313	36	0.75	1.597	86.2	93	-16.2364
	9276	0.414	24	0.75	1.612	89.0	93	-10.2003
	9231	0.519	24	0.50	1.075	91.2	93	-5.4276
	1053	0.405	24	1.25	1.646	91.7	93	-4.7901
	9272	0.568	24	2.00	1.691	95.0	93	2.6651

VITA

ROGER STOCKTON

Candidate for the Degree of

Master of Science

Thesis: STAND ESTABLISHMENT OF WINTER WHEAT IN OKLAHOMA, A SURVEY

Major Field: Agronomy

Biographical:

Personal Data: Born in Clinton, Oklahoma, on June 19, 1950, the son of Mr. and Mrs. Charles Stockton. Married August 6, 1976, Rosie (Schmidt) Stockton

Education: Graduated from Clinton High School, Clinton, Oklahoma, in May, 1968; received Bachelor of Science Degree in Agronomy from Oklahoma Panhandle State University in May, 1972; completed requirements for the Master of Science Degree at Oklahoma State University in May, 1994.

Professional Experience: Farmed and ranched, May,1972 to August, 1992. Graduate teaching assistant in the Department of Agronomy, Oklahoma State University, August, 1992 to May, 1994.

Member: American Society of Agronomy
Crop Science Society of America

OKLAHOMA STATE UNIVERSITY
INSTITUTIONAL REVIEW BOARD
FOR HUMAN SUBJECTS RESEARCH

Date: 12-03-93 **IRB#:** AG-93-010

Proposal Title: FACTORS AFFECTING STAND ESTABLISHMENT IN WINTER WHEAT IN OKLAHOMA

Principal Investigator(s): Gene Krenzer, Roger Stockton,

Reviewed and Processed as: Exempt

Approval Status Recommended by Reviewer(s): Approved

APPROVAL STATUS SUBJECT TO REVIEW BY FULL INSTITUTIONAL REVIEW BOARD AT NEXT MEETING.
APPROVAL STATUS PERIOD VALID FOR ONE CALENDAR YEAR AFTER WHICH A CONTINUATION OR RENEWAL REQUEST IS REQUIRED TO BE SUBMITTED FOR BOARD APPROVAL. ANY MODIFICATIONS TO APPROVED PROJECT MUST ALSO BE SUBMITTED FOR APPROVAL.

Comments, Modifications/Conditions for Approval or Reasons for Deferral or Disapproval are as follows:

Signature: [signature]
Chair of Institutional Review Board

Date: December 3, 1993