FACTORS AFFECTING EMERGENCE IN

HARD RED WINTER WHEAT

By

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INTRODUCTION

As there has been a scarcity of technical information on the seeding rates of hard red winter wheat in this state, experiments have been conducted to determine the best seeding rate and to determine the effect of seeding rate on the major plant factors which influence yield by Fuller[1] in 1960 and by Schlehuber[2] in 1961.

The results of these two experiments were slightly varied due to environmental effects, however, the findings were rather consistent. The results gave a decreased per cent emergence as the seeding rate increased. Normally, moisture as a limiting factor could be considered as an explanation of the results. However, there was ample moisture at planting time and during the period of emergence in the experiment. Oxygen as a limiting factor could be considered and was reported. No other explanation was made from the scope of these experiments.

Four experiments of this study were made to approach this problem. The objectives included the affect of seed density per unit area, the amount of moisture, inhibiting substances, and depth of seeding on germination and/or emergence.

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[1] W. W. Fuller, Effect of Seeding Rate on Yield and Components of Yield In Three Hard Red Winter Wheat Varieties, Concho, Triumph and C.I. 12871. (unpublished Master of Science Thesis, Oklahoma State University, 1960)

[2] A. M. Schlehuber, (Unpublished data 1960 - 1961).

REVIEW OF LITERATURE

Fuller[3/] reported, in 1960, that a lower per cent emergence was obtained with higher seeding rates as compared with the lowest rate in an experiment with three varieties of hard red winter wheat. Schlehuber[4/] obtained the same results in a similar experiment in 1961. Normally, moisture as a limiting factor could be considered to explain these results. However, during the experiment in the 1958-1959 crop year, there was ample moisture at planting time and during the period of emergence.

Ahlgren et al. (1) recognized that the oxygen level of the soil surrounding the seeds also influenced the germination of seeds. They also reported that adequate supplies of oxygen in the soil are essential for seed germination. Hutchins (10) reported that wheat germinates well when well supplied with water and with temperatures about 22°C., in a soil with an oxygen supplying power of 3.0 milligrams or more per square meter per hour. Wheat apparently failed to germinate when the oxygen supplying power was below 1.5 milligram per square meter per hour. Nakayama (16) stated that emergence was reduced by one-half when oxygen pressure was 1 per cent. Taylor (18) reported that the total carbon dioxide production likewise declined for wheat but increased with rice and reached a maximum as oxygen pressure approached zero. Mack (13)

[3/] See Footnote 1/

[4/] See Footnote 2/

stated that the general effects on respiration of a wide variety of plants show an independency of oxygen until a partial pressure of 2 per cent oxygen is reached. Vlamis and Davis (19) reported that an extreme sensitivity to oxygen deficiency is demonstrated by barley seeds under germination.

All of the above experiments have shown oxygen could be a limiting factor which affects germination when it is below the minimum requirement.

Dorywalski et al. (4) reported in an experiment with maize that as the depth of covering seed increased, retardation of seedling development took place. This retardation was especially noticeable after exceeding a depth of 9 cm. Deeper seeding resulted in a lower percentage of seedling development. Hutchins (10) found that when wheat seeds were planted in a thick layer the seeds which were closest to the surface germinated normally while those closer to the bottom of the layer were slower and more deficient in germination. When a large number of germinating seeds were confined to a small area, the later germinating seeds or deeper seeds were not able to obtain sufficient oxygen to emerge. Beveridge and Wilse (2) reported that the emergence of seedlings of three varieties of alfalfa decreased as depth of seeding was increased. The decrease was particularly serious when seed was more than 1.0 inch below the surface. Jones (11) reported that the germination of rice on the surface of submerged soil has been found to be superior to that of seed placed below the soil.

The emergence of seedlings in relation to depth of seeding was discussed above. However, depth of seeding could not be said to affect germination independently.

Millar et al. (14) discussing the relationship between soil aeration and soil moisture, stated that soil aeration is governed primarily by fluctuations in soil moisture. Aeration increases with a decrease in soil moisture, whereas an excess of water tends to encourage anaerobic condition. Hudspeth and Taylor (9) reported that seven days after planting of Blackwell switchgrass on Pullman clay loam, 30% emergence was obtained with 12 per cent moisture, or about 3 atmospheres moisture tension; lower emergence was obtained with moisture higher than 18 to 19 per cent. No emergence occurred when the soil moisture tension was maintained near 10 atmospheres. Hanks and Thorp (7,8) reported that the ultimate seedling emergence of wheat, measured on three soils, was approximately the same when the soil moisture content was maintained between field capacity and permanent wilting percentage, if other factors were optimum for seedling emergence. Doneen and MacGillivray (3) found that most vegetable seeds gave good germination over the range of soil moisture contents from field capacity to permanent wilting percentage.

Moisture in soil is one of the important factors which affect seed emergence. However, in the above - cited experiments moisture could not be considered as a limiting factor in the cultivated land, since most seeds gave germination over the range of soil moisture contents from field capacity to permanent wilting percentage.

Evenari (5) reported that inhibition of germination is the result of germination-inhibiting substances which diffuses from seed or fruit and may accumulate in the germination bed. These germination inhibitors are water-soluble and may be extracted with water from seed or fruit. Mosheov (15) presented his results that the external parts of wheat seeds contain a germination-inhibiting substance. The failure of cereal grains to germinate in the presence of tomato juice may be attributed to a number of causes, such as oxygen deficiency or the presence of special germination-inhibiting substances as reported by Konis (12).

Hagan (6) indicated that the rate and completeness of germination were affected by temperature, moisture, oxygen, light, carbon dioxide, soil ph, mineral elements, activities of microorganisms, and mechanical impedance of the soil. Hanks and Thorp (7,8) stated that there is no doubt that in some instances both oxygen diffusion rate and crust strength were important. These investigations found that when the diffusion rate was limiting, the nonemerging seeds had not germinated; whereas, when crust strength seemed to be the most important factor, the seeds had germinated and the seedlings had made considerable growth but had not penetrated the surface crust. They also reported that if some factor associated with air pore space is the principal limiting factor, it would be expected that seedling emergence would increase as the moisture content decreased at constant bulk density.

MATERIALS AND METHODS

The three varieties of hard red winter wheat used in this study were Concho C.I., 12571, Kaw C.I., 12871 and Triumph C.I., 12132.

Four experiments were carried out to investigate some factors which cause a decrease of germination and/or emergence as the seeding rate is increased. The experimental procedures were as follows:

Experiment 1.

1. Selected wheat seeds were immersed in water for five hours. (900 seeds in 100 cc water)
2. Seeds were then placed in three sizes of test tubes, 10, 15 and 20 cc.
3. Three quantities of seeds, 50, 100 and 150 seeds per test tube (stopped with cotton), were tested in each size of tube.
4. Each treatment was replicated 3 times.
5. Number of emerged seeds was counted a week after test.

The objective of this test was to investigate the relationship between the germination of wheat seedlings and the number of seeds in the test tubes.

Experiment 2.

1. To obtain a water extract of wheat seeds, selected seeds were counted and immersed in a definite quantity of water for three hours (20 grams in 50 cc of water); then the water was poured off and filtered through filter paper.

2. Water extracted seeds were wiped on clean filter paper, and then placed in Petri dishes.
3. Seeding rates used in the test were 40, 80, and 120 seeds per Petri dish (3 3/4 inches).
4. Petri dishes were padded with blotting paper which maintained the moisture conditions. One, two, and three layers of blotting paper were used, and then one, two, and three units of water (1 unit = 5 cc) or water extract of wheat seeds were applied to them respectively.
5. Seeds placed in the Petri dishes were exposed to air. Number of seedlings were counted 10 days after seeding.
6. Factorial arrangement used:
   a. Seeding rate: 40 seeds 80 seeds 120 seeds
   b. Amount of water or water extract applied:
      b_1: One layer of blotting paper with one unit of water or water extract of wheat seeds.
      b_2: Two layers of blotting paper with two units of water or water extract of wheat seeds.
      b_3: Three layers of blotting paper with three units of water or water extracted wheat seeds.
   c. Kind of moisture applied: water and water-extract from wheat seeds.

This experiment was designed to investigate whether or not an interaction existed between seeding rates and inhibiting substances of the seed coat and if these substances were responsible for a decrease of germination as the seeding rate was increased.

Experiment 3.

1. Water extracted seed and unextracted seeds were used in the test. Extracted seeds were obtained from the seeds soaking in the definite quantity of water for three hours as in Experiment 2; then seeds were dried at room temperature (around 70°F.) for two days.
2. Seeds were planted at four rates in wooden flats (20" x 15") consisting of a preirrigated set and a non-preirrigated set, in rows 15 inches long and 1 3/4 inches between rows. Sandy loam soil was used. Planted seeds were covered with approximately 1 cm. of soil.
3. Split plot design was used in the test.
   Moisture conditions: preirrigated set and non-preirrigated set.
   Seed treatments: water-extracted seed and unextracted seed.
   Seeding rates: 20, 30, 40, and 50 seeds per row.
4. First watering was applied immediately after planting and subsequently to both sets every three days. Considerably more water was applied to the preirrigated set.
5. Emerged seedlings were counted 10 days after planting.

The objective of this experiment was to investigate whether an interaction of the inhibiting substances, or gas formation and seeding rate is responsible for the decrease of per cent emergence under soil conditions.

Experiment 4.

1. Water-extracted seed and unextracted seed were used in the test. Extracted seeds were obtained according to the procedures in Experiment 3.

2. Three seeding rates of wheat seeds were planted at 3 different depths in pots (8" diameter) filled with moist sandy loam soil.

3. Complete randomized design of factorial experiment was used.

   Seed treatments: water-extracted and unextracted seed.

   Seeding rates: 30, 60, and 90 seeds per pot.

   Depth of planting: 1 inch, 2 inches and 3 inches.

4. Emerged seedings were counted two weeks after planting.

This experiment was mainly designed to investigate whether or not oxygen is a limiting factor responsible for a decrease of emergence as the seeding rate is increased.

Experiments 1 and 2 were conducted in the basement of the small grain building; experiments 3 and 4 were conducted in the small grains greenhouse on the Agronomy Farm at Stillwater, Oklahoma during the 1962-1963 academic year.

EXPERIMENTAL RESULTS

Experimental results are summarized for each experiment. Table 1-a shows the summary data of the number of seeds tested per test tube, number of seeds germinated per test tube, per cent germination of each treatment for the varieties of Concho and Kaw in experiment 1.

Table 1-b shows an analysis of variance for the per cent germination based on table 1-a, and the individual comparisons between any two means of each source of variation. These data show that the differences among the effects of the different quantity of seeds tested and among the effects of different size of test tubes were significant at the 1% level for Concho; also that the difference among the quantity of seeds was not significant at the 5% level. The difference among the effects of different size of test tubes was significant at the 1% level for Kaw.

The data also show the lower the rate of seeds, the higher the per cent germination. For the three quantities of seeds (50, 100 and 150 seeds per test tube), the average germination was 86.16%, 84.67% and 83.84%, respectively, for Kaw, and 79.90%, 76.44% and 73.93%, respectively, for Concho (Figure 1-b). When the differences among the quantity of seeds within each size of the test tubes used in the test are considered, the lower the quantity of seeds per test tube, the higher the per cent germination is shown in the data.

The experimental results also indicated that the larger the space inside the test tube, the higher the per cent germination for both

Concho and Kaw (See Fig. 1-a). The variations within each level of the number of seeds in the test show the same tendency as mentioned above. The average germination for the three sizes of test tubes, 10 cc, 15 cc and 20 cc were 71.22%, 77.74% and 81.18% respectively for Concho, and 81.26%, 85.44% and 88.19% respectively for Kaw.

TABLE 1-a

SUMMARY DATA SHOWING NUMBER OF SEEDS TESTED PER TEST TUBE, NUMBER OF GERMINATED SEEDS, PER CENT GERMINATION, AND AVERAGE PER CENT GERMINATION OF EACH TREATMENT

EXPERIMENT 1

Variety	Number of seed tested Per Tube	Rep.	10 cc Test Tube No. of Seeds Germinated	%	15 cc Test Tube No. of Seeds Germinated	%	20 cc Test Tube No. of Seeds Germinated	%
Kaw	50	1	43	86.00	45	90.00	47	94.00
		2	42	84.00	42	84.00	41	82.00
		3	41	82.00	44	88.00	45	90.00
		Av		84.00		87.33		88.67
	100	1	80	80.00	88	88.00	90	90.00
		2	83	83.00	83	83.00	93	93.00
		3	79	79.00	84	84.00	82	82.00
		Av		80.67		85.00		87.22
	150	1	123	82.00	125	83.33	134	89.33
		2	119	79.33	131	87.33	131	87.33
		3	114	76.00	122	81.33	128	85.33
		Av		79.11		83.99		87.22
Concho	50	1	38	76.00	41	82.00	41	82.00
		2	34	78.00	39	78.00	40	80.00
		3	42	84.00	42	84.00	43	86.00
		Av		76.00		81.33		82.67
	100	1	72	72.00	73	73.00	85	85.00
		2	68	68.00	81	81.00	80	80.00
		3	69	69.00	79	79.00	81	81.00
		Av		69.69		77.67		82.00
	150	1	104	69.33	111	74.00	121	80.67
		2	102	68.00	114	76.00	119	79.33
		3	103	68.67	109	72.67	115	76.67
		Av		68.67		75.57		78.67

TABLE 1-b

ANALYSIS OF VARIANCE FOR PER CENT GERMINATION BASED ON TABLE 1-a AND INDIVIDUAL COMPARISON BETWEEN ANY TWO MEANS OF EACH SOURCE OF VARIATION

Sources of Variation	df	Mean Square	
		Concho	Kaw
Quantity of Seeds (A)	2	83.7998**	23.3591
Size of tubes (B)	2	219.6021**	102.3377**
A x B	4	6.8806	2.8043
Error	18	13.1923	12.9670
Total	26		

**Significantly different at the 1% level.

Concho:

(1) Difference between the effects of different space (oxygen content) inside the test tubes.

Test tube (size)	10 cc	15 cc	20 cc
$\bar{x}$ % (germination)	71.22	77.74	81.18

L.S.D. at the 5% level = 3.597   L.S.D. at the 1% level = 4.927

(2) Difference between the effects of different quantity of seeds tested.

No. of seeds	50 per tube	100 per tube	150 per tube
$\bar{x}$ % (germination	79.90	76.44	73.93

L.S.D. at the 5% level = 3.597   L.S.D. at the 1% level = 4.927

TABLE 1-b (continued)

Kaw:

(1) Difference between the effects of different space inside the test tube.

Test tube (size)	10 cc	15 cc	20 cc
$\bar{x}$ % (germination	81.26	85.44	88.11

L.S.D. at the 5% level = 3.567 L.S.D. at the 1% level = 4.887

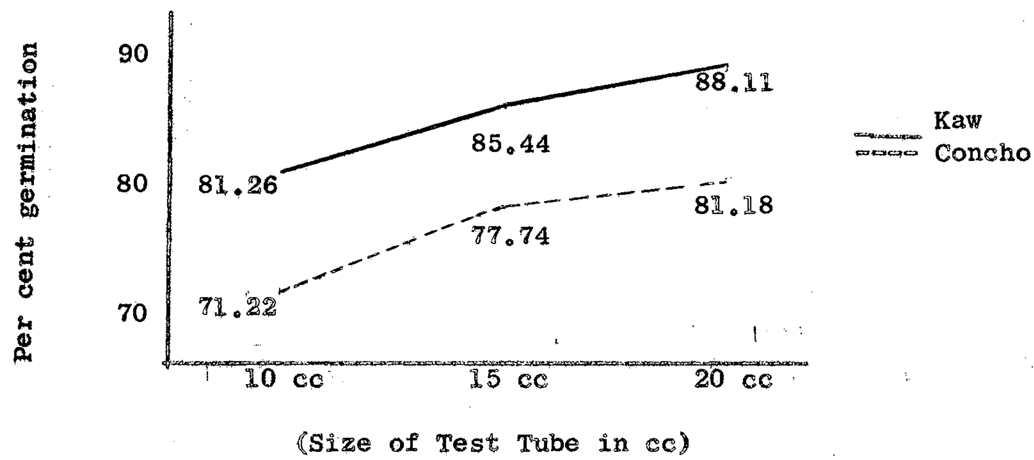


Fig. 1-a. Average germination of two varieties of hard red winter wheat at three sizes of test tubes in experiment 1.

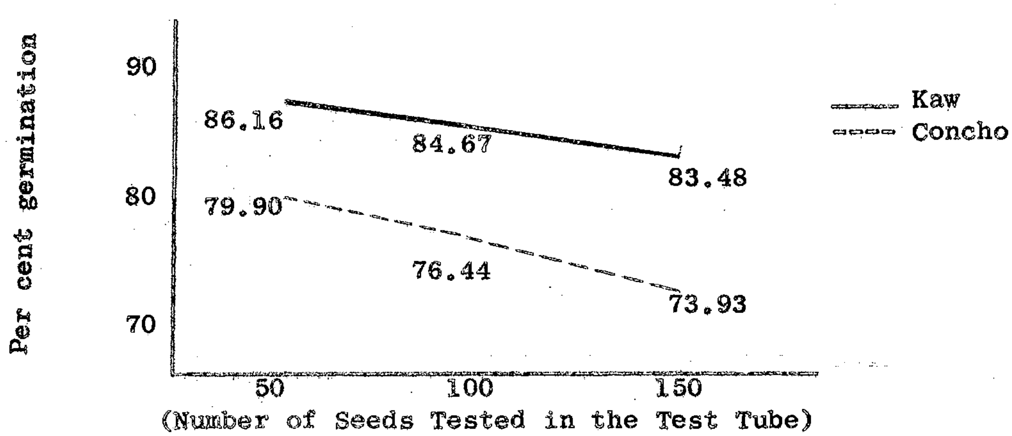


Fig. 1-b. Average germination of two varieties of hard red winter wheat at three quantities of seeds in experiment 1.

Table 2-a shows the summary data of seeding rates per Petri dish, number of seeds germinated, per cent germination and average per cent germination of each treatment in experiment 2.

The analysis of variance for per cent germination data based on Table 2-a is presented in Table 2-b. The data show that the per cent germination among the effects of the seeding rates, among the effects of the moisture conditions and between the effects of solutions (water and water extract of seeds coat) applied to the seeds were not significantly different respectively in the test. (Oxygen might not be a limiting factor for germination in this test, since seeds were exposed to air.) Interaction of seeding rates x moisture conditions x kinds of solutions applied showed significant difference at the 5% level for Kaw. This result could be explained by the combined effect of the three factors interaction which affects seed germination of Kaw. It is difficult to interpret the relationships between these three factors. No other significant interaction could be found in all the varieties tested in experiment 2. The difference between the effect of water control and that of water extract of seed coat was not statistically different in the three varieties. All three showed a decrease of germination when water extract of their own seed coat was applied. This might indicate that inhibiting substances exist in the seed coat. This tendency in germination is shown graphically in Figure 2-c. The variations of average germination of the three varieties of wheat at the three seeding rates and at the three levels of moisture conditions are presented graphically in Fig. 2-a and Fig. 2-b respectively.

TABLE 2-a

SUMMARY DATA SHOWING SEEDING RATE PER PETRI DISH, NUMBER OF SEEDS GERMINATED, PER CENT GERMINATION, AND AVERAGE PER CENT GERMINATION OF EACH TREATMENT

EXPERIMENT 2

			WATER CONTROL						WATER EXTRACT OF SEED					
			1 Unit*		2 Unit**		3 Unit***		1 Unit*		2 Unit**		3 Unit***	
Variety	Seeding Rate Per Petri Dish	Rep.	No. of Seeds Germinated	%	No. of Seeds Germinated	%	No. of Seeds Germinated	%	No. of Seeds Germinated	%	No. of Seeds Germinated	%	No. of Seeds Germinated	%
Concho	40	1	33	82.50	37	92.50	34	85.00	39	97.50	38	95.00	35	87.50
		2	37	92.50	38	95.00	36	90.00	38	95.00	37	92.50	37	92.50
		3	35	87.50	38	95.00	38	95.00	31	77.50	32	80.00	31	77.50
		4	33	82.50	39	97.50	35	87.50	35	87.50	36	90.00	36	90.00
		Av		86.25		95.00		89.37		89.37		89.75		86.87
	80	1	77	96.25	78	97.75	76	95.00	75	93.75	77	96.25	72	90.00
		2	62	75.00	73	91.25	70	87.50	60	75.00	61	76.25	70	87.50
		3	77	96.25	75	93.75	69	86.25	71	88.75	70	87.50	67	83.75
		4	75	92.75	73	91.25	71	88.75	57	71.25	71	88.75	76	95.00
		Av		90.31		93.50		89.37		82.19		87.19		87.06
	120	1	113	94.16	113	94.16	110	91.66	112	93.33	116	96.67	108	90.00
		2	110	91.66	108	90.00	106	88.33	111	92.50	103	85.83	109	90.83
		3	116	96.67	106	88.33	108	90.00	112	93.33	108	90.00	103	85.83
		4	109	90.83	110	91.66	104	86.66	107	89.17	108	90.00	104	86.66
		Av		93.33		91.04		89.16		92.08		90.63		88.33

TABLE 2-a (Continued)

Variety	Seeding Rate Per Petri Dish	Rep.	WATER CONTROL						WATER EXTRACT OF SEED					
			1 Unit*		2 Unit**		3 Unit***		1 Unit*		2 Unit**		3 Unit***	
			No. of Seeds Germinated	%	No. of Seeds Germinated	%	No. of Seeds Germinated	%	No. of Seeds Germinated	%	No. of Seeds Germinated	%	No. of Seeds Germinated	%
Kaw	40	1	39	97.50	40	100.00	38	95.00	37	92.50	37	92.50	39	97.50
		2	38	95.00	38	95.00	38	95.00	38	95.00	38	95.00	40	100.00
		3	38	95.00	40	100.00	37	92.50	38	95.00	37	92.50	37	92.50
		4	37	92.50	40	100.00	39	97.50	39	97.50	37	92.50	39	97.50
		Av		95.00		98.75		95.00		95.00		93.13		96.87
	80	1	76	95.00	76	95.00	75	93.75	76	95.00	78	97.75	74	92.50
		2	77	96.25	75	93.75	77	96.25	75	93.75	79	98.75	73	91.37
		3	75	93.75	79	98.75	77	96.25	77	96.25	73	91.37	78	97.75
		4	78	97.75	79	98.75	79	98.75	77	96.25	79	98.75	79	98.75
		Av		95.69		96.55		96.25		95.30		96.65		95.22
	120	1	116	96.67	114	95.00	118	98.33	118	98.33	118	98.33	117	97.50
		2	115	95.82	118	98.33	115	95.82	118	98.33	114	95.00	114	95.00
		3	116	96.67	107	89.17	116	96.67	112	93.33	116	96.67	115	95.82
		4	117	97.50	118	98.33	118	98.33	117	97.50	118	98.33	118	98.33
		Av		96.67		95.21		97.29		96.87		97.08		96.46

TABLE 2-a (Continued)

Variety	Seeding Rate Per Petri Dish	Rep.	WATER CONTROL						WATER EXTRACT OF SEED					
			1 Unit* No. of Seeds Germinated	%	2 Unit** No. of Seeds Germinated	%	3 Unit*** No. of Seeds Germinated	%	1 Unit* No. of Seeds Germinated	%	2 Unit** No. of Seeds Germinated	%	3 Unit*** No. of Seeds Germinated	%
Triumph	40	1	37	92.50	37	92.50	38	95.00	37	92.50	37	92.50	37	92.50
		2	38	95.00	37	92.50	35	87.50	38	95.00	32	80.00	38	95.00
		3	34	85.00	35	87.50	38	95.00	37	92.50	35	87.50	35	87.50
		4	38	95.00	38	95.00	34	85.00	37	92.50	37	92.50	33	82.50
		Av		91.87		91.87		93.12		91.25		88.13		89.37
	80	1	75	93.75	71	88.75	73	93.75	76	95.00	69	86.25	71	88.75
		2	71	88.75	71	88.75	72	90.00	73	91.25	72	90.00	71	88.75
		3	71	88.75	74	90.50	70	87.50	73	91.25	72	90.00	72	90.00
		4	73	91.25	71	88.75	76	95.00	74	92.50	71	88.75	70	87.50
		Av		90.62		89.44		91.56		92.50		88.75		88.75
	120	1	110	91.66	111	92.50	108	90.00	114	95.00	106	88.33	105	87.50
		2	108	90.00	108	90.00	108	90.00	107	89.17	110	91.66	94	78.33
		3	110	91.66	107	89.17	106	88.33	109	90.83	111	92.50	105	87.50
		4	108	90.00	111	92.50	111	92.50	112	93.33	107	89.17	106	88.33
		Av		90.83		91.04		90.21		91.58		90.41		85.41

*One layer of blotting paper with one unit of water or water extract of seed.
**Two layers of blotting paper with two units of water or water extract of seed.
***Three layers of blotting paper with three units of water or water extract of seed.

TABLE 2-b

ANALYSIS OF VARIANCE FOR PER CENT GERMINATION
OF EACH TREATMENT IN EXPERIMENT 2

Sources of Variation	df	Mean Square		
		Concho	Kaw	Triumph
Seeding rate (A)	2	26.2633	6.3771	5.8068
Amount of solution (B)	2	41.8556	1.6730	24.2565
Kind of moisture (C)	1	116.8410	3.0969	40.9362
A X B	4	34.0289	2.5074	8.4578
A X C	2	34.4523	4.4383	2.0657
B X C	2	13.1086	2.9228	29.6294
A X B X C	4	30.6546	15.8424*	8.2008
Error	54	29.9845	5.7213	10.9434
Total	71			

*Significantly different at 5% level.

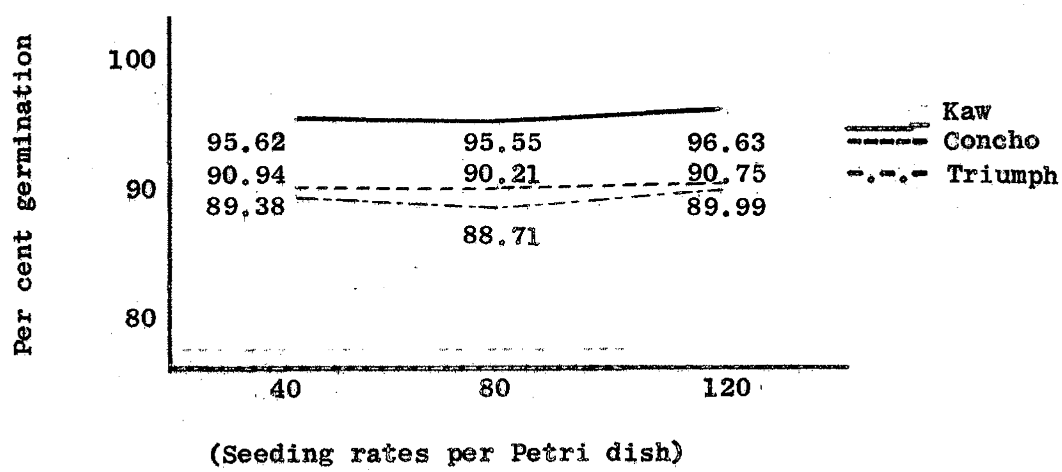
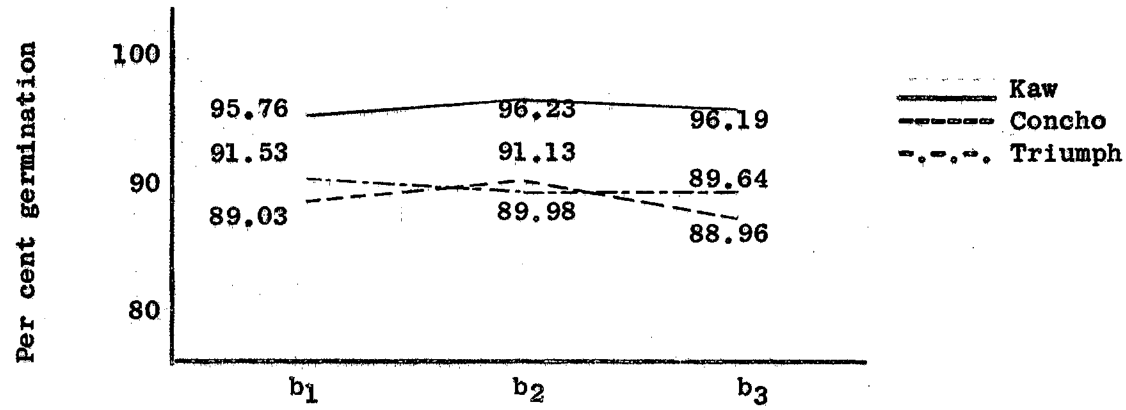


Fig. 2-a. Average germination of three varieties of hard red winter wheat at three seeding rates in experiment 2.



b_1 1 layer of blotting paper with 1 unit of solution.
b_2 2 layers of blotting paper with 2 units of solution.
b_3 3 layers of blotting paper with 3 units of solution.

Fig. 2-b. Average germination of three varieties of hard red winter wheat at three levels of moisture condition in Petri dishes.

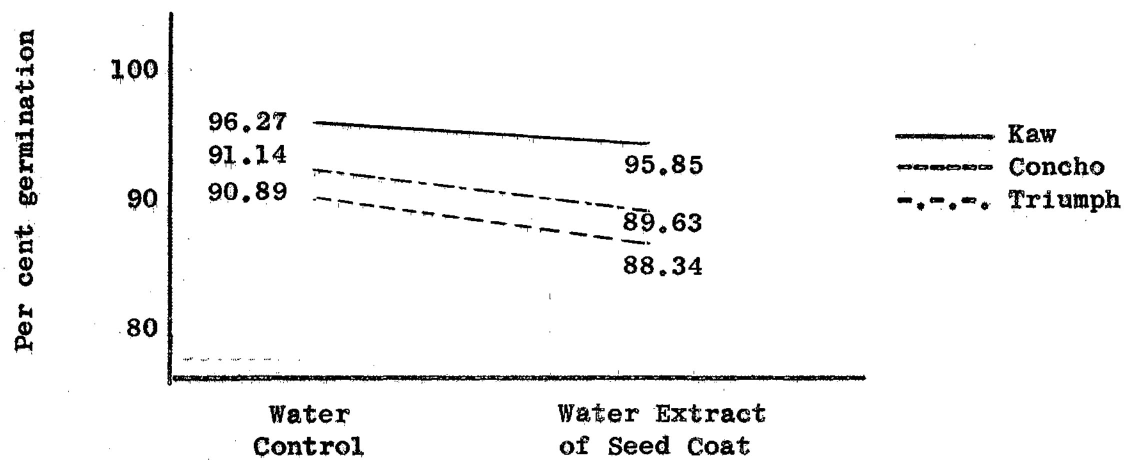


Fig. 2-c. Average germination of three varieties of hard red winter wheat at two kinds of solution, water control and water extract of their own seed coat, in experiment 2.

Table 3-a shows the summary data of seeding rates per row, number of emerged seedlings per row, per cent emergence per row, and average per cent emergence of each treatment in experiment 3.

Table 3-b shows the summary data of analysis of variance for per cent emergence based on Table 3-a, and individual comparison between any

two means of each source of variation. The data show that the differences in emergence for Concho between moisture conditions (pre-irrigated and non-preirrigated) and between the seed treatments (water extracted seed and unextracted seed) were significant at the 5% level. The AOV also shows the effect of seeding rate on emergence for Triumph was significant at the 5% level. Other effects were not statistically different in this test.

The differences between the average effects of preirrigation and non-preirrigation are shown graphically in Fig. 3-a. It shows a higher emergence in non-preirrigated plots and the lower emergence in preirrigated plots for Concho and Triumph but not for Kaw. The difference was not significant for Triumph but the trend was the same as for Concho. Kaw showed a reverse tendency although it was not statistically significant.

Fig. 3-b shows the difference between the average effects of water extracted seed and unextracted seed. Difference between the average effects of water extracted seed and unextracted seed was significant at the 5% level for Concho; emergence was 81.02% and 73.79% respectively. It showed higher emergence in the extracted seed and lower emergence in the unextracted seed. Higher emergence in extracted seed, lower emergence in unextracted seed were also found both in preirrigated and non-preirrigated plots. However, neither Kaw or Triumph responded like Concho.

Variations of emergence at four seeding rates in experiment 3 are presented in Fig. 3-c. The data showed a more or less decrease of emergence as the seeding rate was increased except that for Triumph the highest seeding rate (50 seeds per row) showed higher emergence than the 40 - and 30 - seed rate.

TABLE 3-a

SUMMARY DATA SHOWING SEEDING RATES PER ROW, NUMBER OF EMERGED SEEDLINGS, PER CENT EMERGENCE OF EACH TREATMENT UNIT AND AVERAGE PER CENT EMERGENCE OF EACH TREATMENT

EXPERIMENT 3

			PREIRRIGATED				NON-PREIRRIGATED			
			Extracted Seeds		Unextracted Seeds		Extracted Seeds		Unextracted Seeds	
Variety	No. of Seeds Planted Per Row	Rep.	No. of Seedling Emerged	%	No. of Seedling Emerged	%	No. of Seedling Emerged	%	No. of Seedling Emerged	%
Concho	20	1	17	85.00	14	70.00	17	85.00	17	85.00
		2	14	70.00	16	80.00	16	80.00	17	85.00
		3	17	85.00	11	55.00	16	80.00	14	70.00
		Av		83.33		68.33		81.67		83.33
	30	1	20	66.67	21	70.00	25	83.33	26	86.67
		2	27	90.00	27	90.00	26	86.67	19	63.33
		3	24	80.00	24	80.00	24	80.00	22	73.33
		Av		78.89		80.00		83.33		74.44
	40	1	30	75.00	32	80.00	34	85.00	29	72.50
		2	31	77.50	28	70.00	38	95.00	29	72.50
		3	30	75.00	27	67.50	35	87.50	32	80.00
		Av		75.83		72.50		89.17		75.00
	50	1	32	64.00	33	66.00	41	82.00	32	64.00
		2	39	78.00	33	66.00	42	84.00	39	78.00
		3	42	84.00	33	66.00	43	86.00	40	80.00
		Av		75.33		66.00		84.00		74.00

TABLE 3-a (Continued)

Variety	No. of Seeds Planted Per Row	Rep.	PREIRRIGATED Extracted Seeds No. of Seedling Emerged	%	PREIRRIGATED Unextracted Seeds No. of Seedling Emerged	%	NON-PREIRRIGATED Extracted Seeds No. of Seedling Emerged	%	NON-PREIRRIGATED Unextracted Seeds No. of Seedling Emerged	%
Kaw	20	1	17	85.00	17	85.00	19	95.00	20	100.00
		2	20	100.00	19	95.00	18	90.00	20	100.00
		3	20	100.00	20	100.00	17	85.00	19	95.00
		Av		95.00		93.33		90.00		98.33
	30	1	28	93.33	29	96.67	30	100.00	29	96.67
		2	28	93.33	28	93.33	25	83.33	28	93.33
		3	29	96.67	29	96.67	29	96.67	27	90.00
		Av		94.44		95.56		93.33		93.33
	40	1	38	95.00	38	95.00	36	90.00	40	100.00
		2	40	100.00	37	92.50	37	92.50	37	92.50
		3	39	97.50	38	95.00	39	97.50	36	90.00
		Av		97.50		94.17		93.33		94.00
	50	1	45	90.00	44	88.00	46	92.00	44	88.00
		2	46	92.00	45	90.00	46	92.00	47	94.00
		3	46	92.00	45	90.00	48	96.00	46	92.00
		Av		91.33		89.33		93.33		91.33
Triumph	20	1	14	70.00	13	65.00	18	90.00	15	75.00
		2	13	65.00	15	75.00	18	90.00	17	85.00
		3	15	75.00	19	95.00	18	90.00	18	90.00
		Av		70.00		78.33		90.00		83.33
	30	1	21	70.00	19	63.33	25	83.33	27	90.00
		2	25	83.33	21	70.00	28	93.33	25	83.33
		3	24	80.00	23	76.67	26	86.67	22	73.33
		Av		77.78		69.90		87.78		82.22
	40	1	26	65.00	29	72.50	27	67.50	28	70.00
		2	27	67.50	28	70.00	34	85.00	35	87.50
		3	32	80.00	34	85.00	29	72.50	28	70.00
		Av		70.83		75.83		75.33		75.83
	50	1	36	72.00	32	64.00	39	78.00	41	82.00
		2	37	74.00	40	80.00	42	84.00	45	90.00
		3	43	86.00	43	86.00	41	82.00	41	82.00
		Av		77.33		76.67		81.33		84.67

TABLE 3-b

ANALYSIS OF VARIANCE FOR PER CENT EMERGENCE BASED ON TABLE 3-a AND INDIVIDUAL COMPARISON BETWEEN ANY TWO MEANS OF EACH SOURCE OF VARIATION

Sources of Variation	df	Mean Square		
		Concho	Kaw	Triumph
Degree of Moisture (A)	1	374.9772*	2.2968	753.3506
Error (a)	4	33.3920	36.3927	308.0975
Seeds treatments (B)	1	629.5906*	0.3072	1.9563
A X B	1	24.7968	31.9481	31.3519
Error (b)	4	56.2215	18.2447	21.0771
Seeding Rates (C)	3	40.9774	28.7969	95.2612*
A X C	3	51.8700	10.3525	68.9055
B X C	3	19.7199	15.8811	54.7716
A X B X C	3	71.1958	20.2007	55.3719
Error (c)	24	76.8841	18.4005	31.4236
Total	47			

* Significantly different at the 5% level.
** Significantly different at the 1% level.

Concho:

(1) Difference between the preirrigated and non-preirrigated plot (degree of moisture)

Moisture condition	Preirrigated plot	Non-preirrigated plot
$\bar{\bar{x}}$ % (Emergence)	74.16	80.35

L.S.D. at the 5% level = 4.630   L.S.D. at the 1% level = 7.679

(2) Difference between the effects of water extracted seed and unextracted seed (seeds treatments).

Seeds treatments	Extracted seed	Unextracted seed
$\bar{\bar{x}}$ % (Emergence)	81.02	73.39

L.S.D. at the 5% level = 6.007   L.S.D. at the 1% level = 7.679

Triumph:

(1) Differences between the effects of seeding rates.

Seeding rates	20 seeds per row	50 seeds per row	30 seeds per row	40 seeds per row
$\bar{x}$ % (Emergence)	80.42	80.00	79.44	74.37

L.S.D. at the 5% level = 4.722   L.S.D. at the 1% level = 6.340

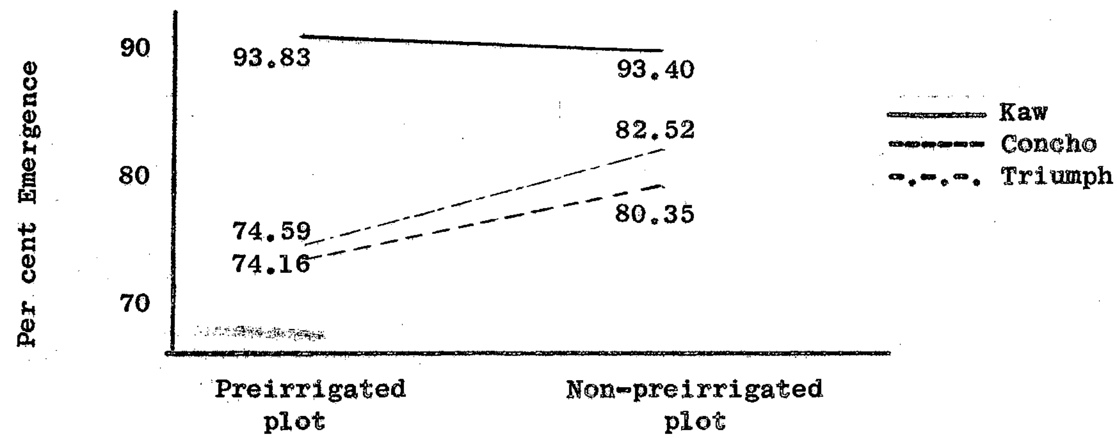


Fig. 3-a. Average emergence of three varieties at two degrees of moisture conditions in experiment 3.

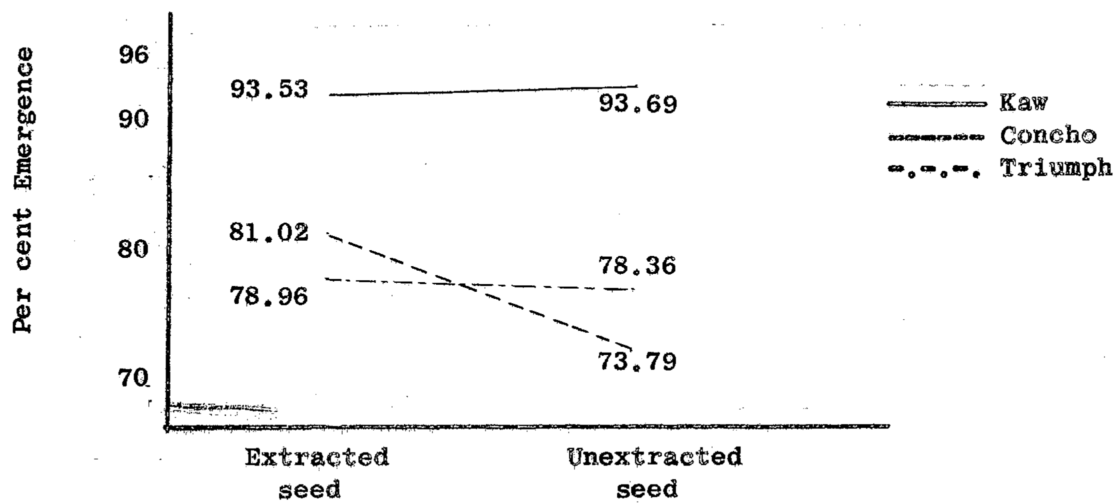


Fig. 3-b. Average emergence of three varieties at 2 kinds of seed treatments in experiment 3.

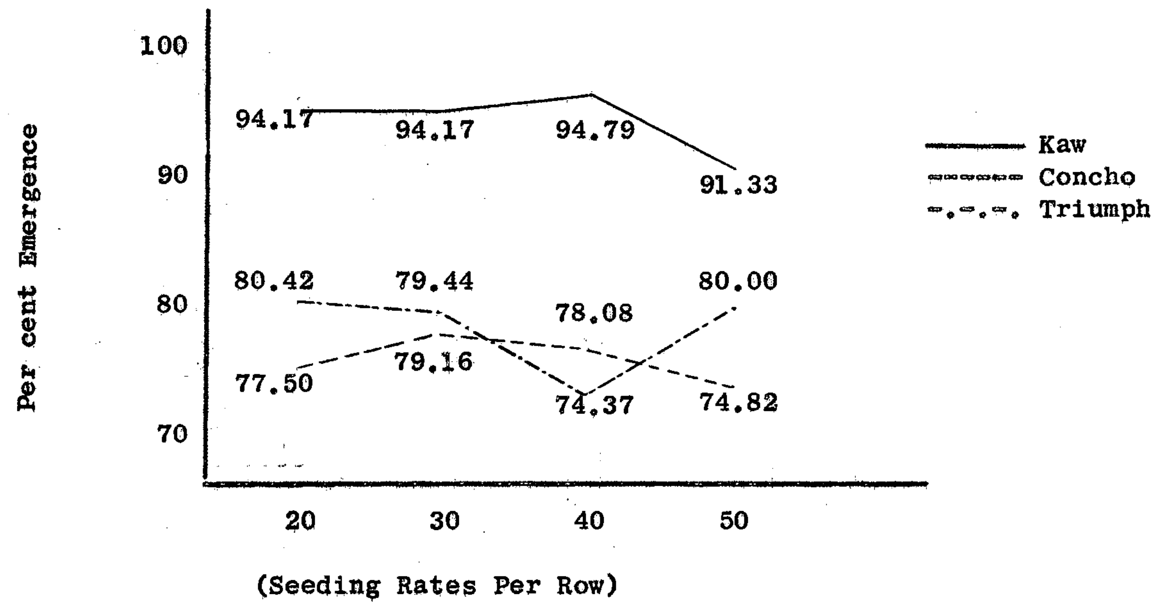


Fig. 3-c. Average emergence of three varieties at four seeding rates in experiment 3.

Data showing number of seed planted per pot, number of emerged seedlings per pot, per cent emergence per pot, and average per cent emergence for each treatment in experiment 4 are presented in Table 4-a.

Table 4-b presents the analysis of variance for per cent emergence based on data from Table 4-a and individual comparisons between any two means of each source of variation. The differences between the effects of extracted seed and unextracted, among the effects of different depth of planting and among the effects of seeding rates were significant at the 1 per cent, 5 per cent and 1 per cent level respectively for Concho, and were significant at the 1 per cent level for Triumph. No difference was found significant for Kaw. Interaction of seed treatments x depth of planting was significant at the 5% level for Triumph. No other interaction was found statistically significant for Concho, Kaw and Triumph.

The difference between the average effects of water extracted seed and unextracted seed is shown graphically in Fig. 4-a. Higher emergence in extracted seed and lower emergence in unextracted seed were found in all of the three varieties tested. Although the difference was not significant for Kaw the tendency for the varieties tested was consistent.

Fig. 4-b shows the graphic comparison among the effects of the depth of planting in experiment 4. The data showed a decrease of emergence as the depth of planting was increased. The differences among the effects of depth of planting were significant for Concho and Triumph but not for Kaw, however, the tendency was very much consistent.

Variation of emergence at the three seeding rates (30, 60 and 90 seeds per pot) tested for Concho, Kaw and Triumph is shown graphically in Fig. 4-c. The results showed a decrease of emergence as the seeding rates were increased. This tendency was very obvious for Concho and Triumph but not for Kaw. Though there was no statistical difference, Kaw showed a tendency for increased seeding rate to reduce emergence percentage.

Emergence at three seeding rates, 30 seeds, 60 seeds, and 90 seeds per pot, was 75.37%, 66.20%, and 59.51% respectively for Concho; 66.57% 62.31%, and 59.51% respectively for Triumph and 79.99%, 77.69%, and 78.74% respectively for Kaw.

Concho and Triumph show an interaction between seed treatment (extracted and unextracted) and depth of planting (Fig. 4-d). This possibly indicates that the effects of inhibiting substances become more pronounced as the depth of seeding is increased.

TABLE 4-a

SUMMARY DATA SHOWING NUMBER OF SEED PLANTED PER POT, NUMBER EMERGED SEEDLINGS, PER CENT EMERGENCE, AND AVERAGE PER CENT EMERGENCE OF EACH TREATMENT

EXPERIMENT 4

			Unextracted Seed						Extracted Seed					
			1 in. depth		2 in. depth		3 in. depth		1 in. depth		2 in. depth		3 in. depth	
Variety	No. seed planted per pot	Rep.	No. of Seedling Emerged	%	No. of Seedling Emerged	%	No. of Seedling Emerged	%	No. of Seedling Emerged	%	No. of Seedling Emerged	%	No. of Seedling Emerged	%
Concho	30	1	26	86.67	24	80.00	18	60.00	21	70.00	23	76.67	23	76.67
		2	23	76.67	18	60.00	23	76.67	21	70.00	24	80.00	25	83.33
		3	22	73.33	22	73.33	14	46.67	26	86.67	27	90.00	27	90.00
		Av		78.89		71.11		61.11		75.56		82.22		83.33
	60	1	41	68.33	21	51.67	34	56.67	44	73.33	51	85.00	52	86.67
		2	38	63.33	35	58.33	36	60.00	43	71.67	32	53.33	40	66.67
		3	38	63.33	39	65.00	27	45.00	45	75.00	43	71.67	46	76.67
		Av		64.99		58.33		53.89		73.33		70.00		76.67
	90	1	54	60.00	58	64.44	41	45.55	63	70.00	48	53.33	60	66.67
		2	66	73.33	43	47.78	47	52.22	69	76.67	51	56.67	41	45.55
		3	60	66.67	58	64.44	43	47.78	65	73.33	43	47.78	53	58.89
		Av		66.67		58.89		48.51		73.33		52.59		57.04

TABLE 4-a (Continued)

			Unextracted Seed						Extracted Seed					
			1 in. depth		2 in. depth		3 in. depth		1 in. depth		2 in. depth		3 in. depth	
Variety	No. seed planted per pot	Rep.	No. of Seedling Emerged	%	No. of Seedling Emerged	%	No. of Seedling Emerged	%	No. of Seedling Emerged	%	No. of Seedling Emerged	%	No. of Seedling Emerged	%
Kaw	30	1	26	86.67	22	73.33	25	83.33	21	70.00	23	76.65	23	76.65
		2	26	86.67	25	83.33	21	70.00	23	76.65	25	83.33	22	73.33
		3	21	70.00	26	86.67	23	76.67	30	100.00	26	86.67	24	80.00
		Av		81.11		81.11		76.67		82.22		82.20		76.66
	60	1	45	75.00	44	73.33	39	65.00	50	83.33	46	76.67	46	76.67
		2	45	75.00	46	76.67	54	90.00	43	71.67	51	85.00	45	75.00
		3	47	78.33	47	78.33	40	66.67	58	96.67	55	91.67	38	63.33
		Av		76.11		76.11		73.89		83.89		84.45		71.67
	90	1	56	62.22	63	70.00	70	77.78	72	80.00	57	63.33	57	63.33
		2	68	75.56	75	83.33	65	72.22	74	82.22	71	78.89	72	80.00
		3	76	84.44	71	78.89	64	71.11	60	66.67	73	81.11	63	70.00
		Av		74.07		77.41		73.70		76.29		74.44		71.11

TABLE 4-a (Continued)

			Unextracted Seed						Extracted Seed					
			1 in. depth		2 in. depth		3 in. depth		1 in. depth		2 in. depth		3 in. depth	
Variety	No. seed planted per pot	Rep.	No. of Seedling Emerged	%	No. of Seedling Emerged	%	No. of Seedling Emerged	%	No. of Seedling Emerged	%	No. of Seedling Emerged	%	No. of Seedling Emerged	%
Triumph	30	1	26	86.67	20	66.67	14	46.67	21	70.00	20	61.67	18	60.00
		2	19	63.33	17	56.67	14	46.67	19	63.33	21	70.00	22	73.33
		3	26	86.67	20	66.67	15	50.00	26	86.67	23	76.65	20	66.67
		Av		78.89		63.34		47.78		73.33		69.22		66.67
	60	1	36	60.00	36	60.00	31	51.67	43	71.67	38	63.33	38	63.33
		2	35	58.33	32	53.33	35	58.33	47	78.33	35	58.33	38	63.33
		3	39	65.00	40	66.67	28	46.69	42	70.00	40	66.67	41	66.67
		Av		61.11		60.00		52.22		73.33		62.78		64.44
	90	1	55	61.11	56	62.22	34	37.78	47	52.22	56	62.22	48	52.22
		2	49	54.44	50	55.56	45	50.00	53	58.89	48	53.33	51	56.67
		3	51	56.67	62	68.89	40	44.44	66	73.33	53	58.89	49	54.44
		Av		57.78		62.22		44.07		61.48		58.15		54.44

TABLE 4-b

ANALYSIS OF VARIANCE FOR PER CENT EMERGENCE BASED ON TABLE 4-a AND INDIVIDUAL COMPARISON BETWEEN ANY TWO MEANS OF EACH SOURCE OF VARIATION IN EXPERIMENT 4

Sources of Variation	df	Mean Square		
		Concho	Kaw	Triumph
Seed treatments (A)	1	1111.8463**	27.1504	541.8801**
Depth of planting (B)	2	371.2951*	160.8902	732.1136**
Seeding Rates (C)	2	1141.8645**	136.8438	480.0905**
A X B	2	262.1743*	33.5781	193.7433*
A X C	2	146.5310	38.6725	35.5725
B X C	4	111.9231	9.1256	74.6178
A X B X C	4	83.7971	16.2860	76.8832
Error	36	73.7363	75.6014	46.1169
Total	53			

* Significantly different at the 5% level.
** Significantly different at the 1% level.

Concho:

(1) Difference between the effects of water-extracted seed and unextracted seed. (seeds treatment)

Seeds treatment	Extracted seed	Unextracted seed
$\bar{x}$ % (Emergence)	71.56	62.49

L.S.D. at the 5% level = 4.742 L.S.D. at the 1% level = 6.361

(2) Difference between the effects of the depth of planting.

Depth of planting	1 in. depth	2 in. depth	3 in. depth
$\bar{x}$ % (Emergence)	72.13	65.52	63.42

L.S.D. at the 5% level = 5.807 L.S.D. at the 1% level = 7.790

(3) Difference between the effects of seeding rates.

Seeding rates	30 seeds per pot	60 seeds per pot	90 seeds per pot
$\bar{x}$ % (Emergence)	75.37	66.20	59.51

L.S.D. at the 5% level = 5.807   L.S.D. at the 1% level = 7.790

Triumph:

(1) Difference between the effects of water extracted seed and unextracted seed. (seeds treatment)

Seed treatment	Extracted seed	Unextracted seed
$\bar{x}$ % (Emergence)	64.89	56.47

L.S.D. at the 5% level = 3.750   L.S.D. at the 1% level = 5.122

(2) Difference between the effects of the depth of planting.

Depth of planting	1 inch depth	2 inches depth	3 inches depth
$\bar{x}$ % (Emergence)	67.59	62.65	54.93

L.S.D. at the 5% level = 4.592   L.S.D. at the 1% level = 6.160

(3) Difference between the effects of seeding rates.

Seeding rates	30 seeds per pot	60 seeds per pot	90 seeds per pot
$\bar{x}$ % (Emergence)	66.57	62.31	56.29

L.S.D. at the 5% level = 4.592   L.S.D. at the 1% level = 6.160

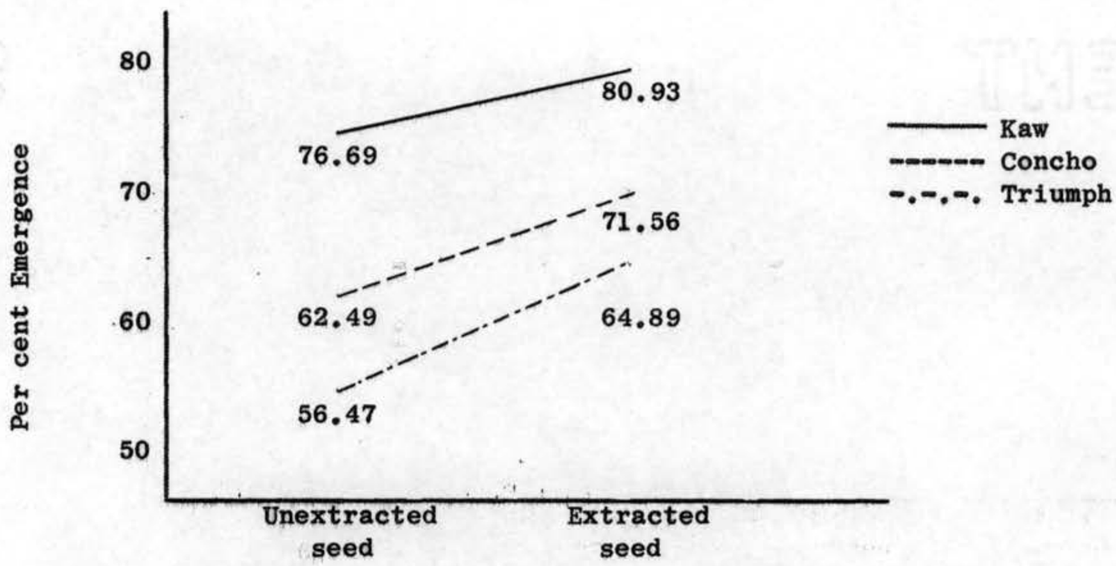


Fig. 4-a. Average emergence of three varieties at two kinds of seed treatments, water-extracted seed and unextracted seed, in experiment 4.

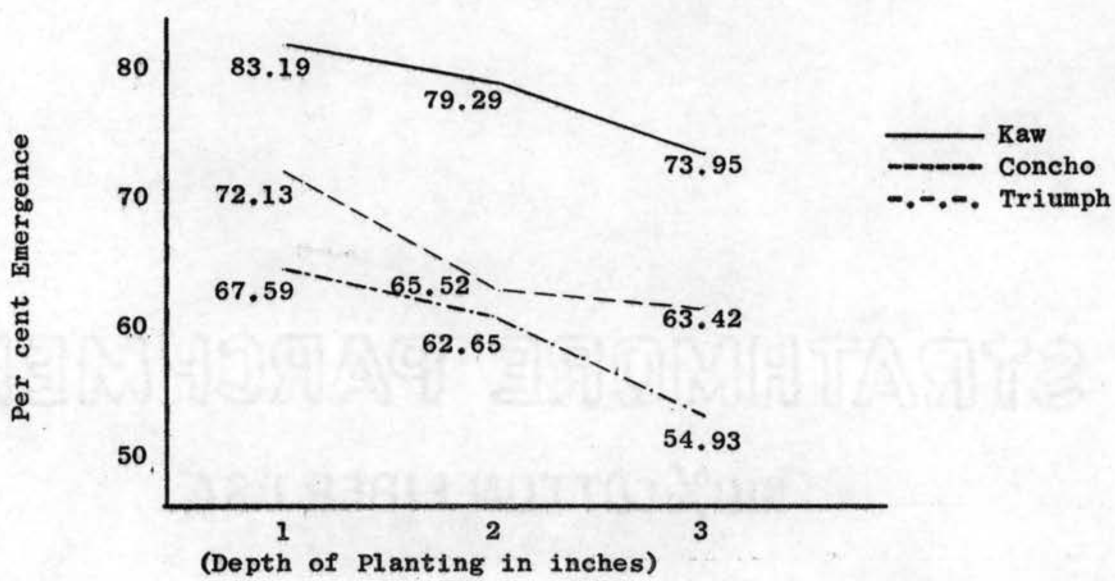


Fig. 4-b. Average emergence of three varieties at three different depths in experiment 4.

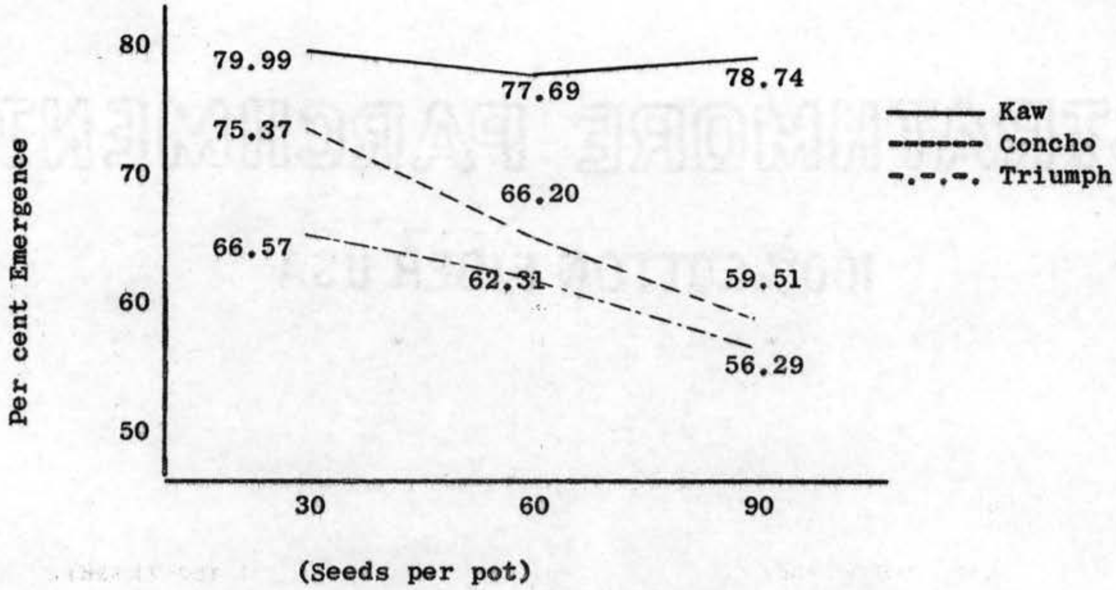


Fig. 4-c. Average emergence of three varieties at three seeding rates.

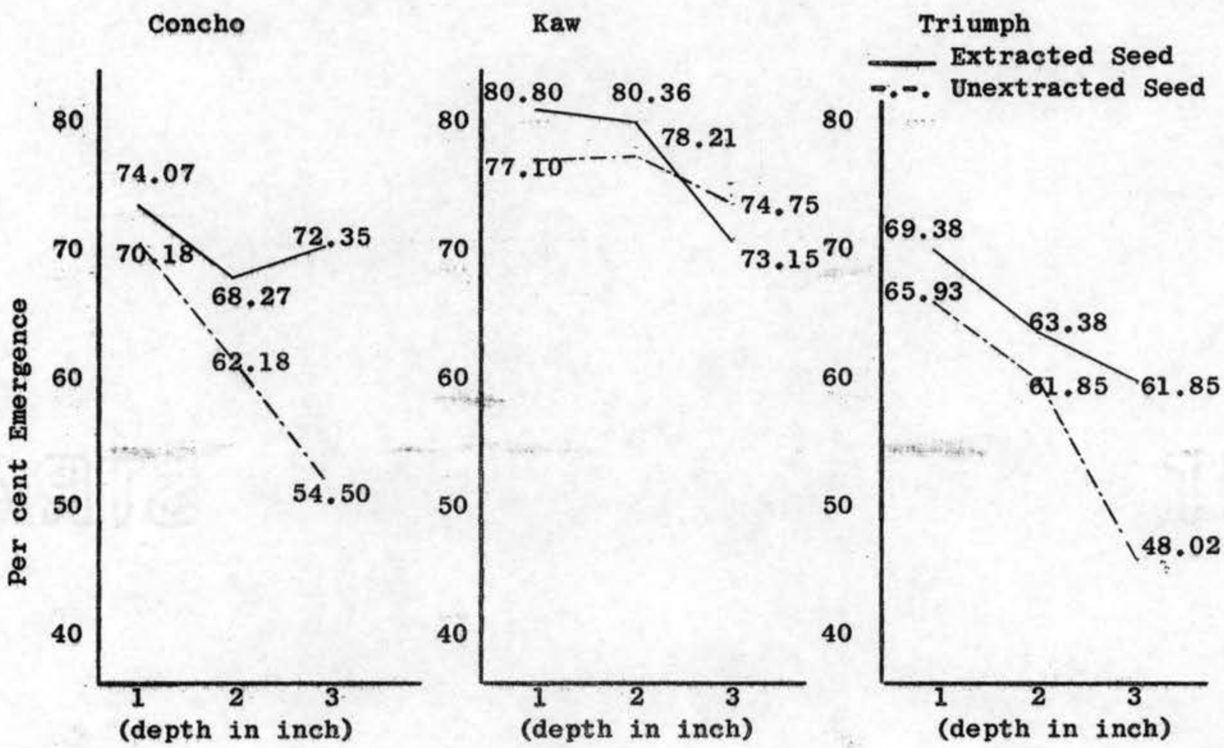


Fig. 4-d. Interaction of seed treatment and depth of planting in experiment 4.

DISCUSSION

Discussion is given on the basis of germination and/or emergence of three varieties of hard red winter wheat tested in four experiments.

In experiment 1, the results showed that the fewer number of seeds tested in a given size test tube and the larger the space inside a given test tube, the higher the per cent germination (Figure 1-a and b). Further, in Table 1-a it can be noted that within each size of test tube, as the number of seeds were increased the percentage germination decreased. The results were highly consistent. Moisture could not be considered as a limiting factor in the test since all seeds tested were soaked in water for the same period of time consequently each seed could absorb almost the same quantity of water. Oxygen, as a limiting factor, could be considered to explain the above results.

Ahlgren et al. (1) reported that the oxygen level of the soil surrounding the seeds also influenced the germination of seeds, and an adequate supply of oxygen in the soil was essential for seed germination. In this experiment, possibly the oxygen content of the two larger-sized test tubes was greater than it was in the smaller test tube. Thus when a large number of germinating seeds were confined to a small area, the oxygen in that area was rapidly depleted. If the oxygen fell below the minimum requirements needed for germination, the later germinating seeds were not able to obtain sufficient oxygen to emerge. Nakayama (16) has reported that wheat seed failed to germinate well when the oxygen-pressure was below 5 per cent, and emergence was decreased around 50 per cent when the oxygen-pressure was 1 per cent.

The above work could possibly explain the lower per cent germination at the higher rate of seeds tested in the experiment. Possibly those seeds tested in the larger test tube obtained more oxygen and were capable of a higher germination than those seeds tested in the smaller test tube. The results imply that oxygen could be one of the important factors which causes a decrease of emergence as the seeding rate is increased.

When oxygen was not a limiting factor for germination as in experiment 2 (since seeds tested were exposed to air), per cent germination among the effects of the different seeding rates, among the effects of different moisture conditions, and between the effects of the solutions (water and water extract of wheat seed coat) applied to seeds were not significantly different (Table 2-b). The relationships between the per cent germination and seeding rates, and between the per cent germination and moisture conditions and between the per cent germination and kind of moisture were vague (Fig. 2-a, 2-b, 2-c). The moisture conditions in experiments 1 and 2 could be considered above the limiting level for germination. If the assumption mentioned above is true, then oxygen can be considered as one of the important factors or the most important factor which affects emergence of wheat seeds as well as causing a decrease of emergence as the seeding rate is increased. No other satisfactory explanation can be offered at this time.

Though the difference between the effect of water control and that of water extract of seed coat was not statistically different in the three varieties, Concho, Kaw and Triumph, all of them showed more or less the same tendency, i.e., a decrease of germination when water extract of their own seed coat was applied (Fig. 2-c). Mosheov (15) recognized that the external parts of wheat seeds contain a germination-inhibiting substance. The inhibiting action of this substance is stronger in the light than in the dark. Evenari (5) stated that the inhibition of germination is the result of germination-inhibiting substances which diffuse from seed or fruit and may accumulate in the germination bed. He also stated that these germination inhibitors are water-soluble and may be extracted with water from seed or fruit.

The above work could account for the decrease of germination when water extract of their own seed coat was applied. The results somewhat implied that inhibiting substances for germination existed in the seed coat of wheat, however, it was rather insignificant.

Interaction of seeding rate x moisture conditions x kinds of solution applied showed statistical significance at the 5 per cent level for Kaw (Table 2-b). This result could be explained by the combined effect of the three factor interaction which affects seed germination of Kaw. Since no other low order interaction was significant, further explanation can hardly be made from the data.

In experiment 3, a significant difference at the 5 per cent level between the effects of preirrigation (higher moisture condition) and non-preirrigation (lower moisture condition) of Concho was obtained. The result showed higher emergence in the non-preirrigated plot and lower emergence in the preirrigated plot (Fig. 3-a). Though the difference was not statistically significant for Triumph, the tendency was the same as for Concho (Fig. 3-a). Kaw showed a somewhat reverse tendency as compared to Concho and Triumph, but it was not significant. Consequently moisture as a limiting factor for emergence could hardly be considered in the result.

Fuller[5/] considered Kaw to require less oxygen for germination than Concho and Triumph. Millar et al. (14) recognized that soil aeration is governed primarily by fluctuations in soil moisture. Aeration increases with a decrease in soil moisture, whereas an excess of water tends to encourage anaerobic conditions. The oxygen level of the soil surrounding the seeds influences the germination of seeds as reported by Ahlgren et al. (1). Their results could possibly explain the experimental results obtained in this experiment. The soil maintained at the higher moisture content probably had fewer air filled pores through which the diffusion of oxygen could take place. Consequently the respiring seeds could not obtain oxygen at a sufficient rate. It could be considered that different quantities of oxygen contained in the soil caused the result mentioned above (Fig. 3-a).

A significant difference at the 5 per cent level between the emergence of water extracted seed and unextracted seed of Concho was obtained; in Kaw and Triumph, no significant differences were found. Higher emergence in extracted seed and lower emergence in unextracted seed of Concho were found (Fig. 3-b). The same tendency was also obtained within both the preirrigated plot and the non-preirrigated plot (Table 3-a Concho). The works of Mosheov (15) and Evenari (5) could explain the result. The emergence of Concho might be affected by the inhibiting substance of its own seed coat; whereas, Kaw and Triumph might not be affected by the inhibiting substance of their own seed coat.

Interactions of the seeding rates x extracted seed and unextracted seed were not statistically significant. No other interaction of the factors concerned in the test was significant. Although inhibiting

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[5/] See Footnote 1/

substances of wheat seed coat could be considered as a factor which affects emergence of wheat seed for some varieties, this factor could not explain a decrease of emergence as the seeding rate is increased.

The difference among the emergence of seeding rates of Triumph was significant at the 5 per cent level. The result showed a decrease of emergence as the seeding rate was increased except the highest seeding rate showed one of the higher emergence percentages. The tendencies of the variation of emergence in three varieties were not exactly the same; however, the lowest emergence was shown in the highest seeding rate except Triumph. Crust strength and bluk density in addition to oxygen diffusion in the soil could be considered factors which influence seed germination and emergence.

The variation in emergence of three varieties in experiment 3 (Fig. 3-a, 3-b, and 3-c) were not highly consistent. The emergence of Kaw was higher than that of Concho and Triumph in every respect.

In experiment 4, lower emergence for unextracted seed and higher emergence for extracted seed was obtained. The tendency of the three varieties was highly consistent (Fig. 4-a). The differences between the effects of extracted seed and unextracted seed on emergence of Concho and Triumph were significant at the 1 per cent level. The external part of the seed coat (inhibiting substance for germination) could be one of the factors which affect seed emergence, but it is difficult to explain independently that the inhibiting substance causes a decrease of emergence as the seeding rate is increased.

The effect of depth of planting on emergence of Concho and Triumph was significant at the 1 per cent level. Though the difference was not statistically significant for Kaw, the tendency was consistent with that of Concho and Triumph. All three varieties of Concho, Kaw and Triumph, showed a decrease in seedling emergence as the depth of seeding was increased (Fig. 4-b). These findings are in accord with those of Beveridge et al. (2), Dorywalski et al. (4), Hutchins (10) and Jones (11). It seems logical to assume that the diffusion rate of oxygen to the seeds would be lower at the deeper seeding depths than for more shallow depths. Consequently, seeds planted at a greater depth may not be able to obtain oxygen at a sufficient rate; the deeper seeds or the later germinating seeds were not able to obtain sufficient oxygen to emerge.

Concho and Triumph showed that the lower emergence for the higher seeding rate was obtained at the 1 per cent significance level; whereas, the variation of Kaw in this respect was not clear (Fig. 4-c). For each planting depth the per cent emergence decreased as the seeding rate increased. For each seeding rate the per cent emergence decreased as planting depth increased. The meaning of these two results probably implies that oxygen content in the soil is one of the most important factors which causes a decrease of emergence as the seeding rate is increased.

No significant interaction of the factors considered was obtained except the interaction of depth of planting x seed treatment (extracted seed and unextracted seed) for Triumph which was significant at the 5 per cent level. Fig. 4-d indicates that the effects of inhibiting substances become more pronounced as the depth of seeding is increased. For each seed treatment (extracted and unextracted seeds) as planting depth increased emergence decreased. For each planting depth with either water-extracted seed or unextracted seed as planting depth increased emergence decreased.

Hagan (6) pointed out that the rate and completeness of germination are affected by temperature, moisture, oxygen, light, carbon dioxide, soil ph, mineral elements, and activities of microorganisms. Hank and Throp (7) stated that mechanical impedance of the soil should be included in addition to a list of the factors influencing seedling emergence listed by Hagan (6).

Among those factors indicated above, oxygen seemed to be the most important factor which affects seed germination and causes a reduced emergence as the rate of seeding is increased. Though oxygen as a limiting factor could be considered, the other factors such as depth of planting and soil properties could not be neglected for further explanation to approach this problem. It is evident from the results of this study, that this problem should be continued with more intensive and extensive work.

SUMMARY

A study of factors affecting the emergence of seedlings at various seeding rates of three varieties of hard red winter wheat was carried out in the laboratory and the greenhouse during the 1962-1963 academic year.

The main objectives of this investigation were: (1) to determine the relationship between emergence and seeding rate; and (2) to determine the factors which influence seedling emergence.

Four experiments were carried out to attack the above problems. The emergence of seedlings with three quantities of seeds was measured in test tubes (experiment 1). The higher the number of seeds per test tube, the lower the per cent germination per test, and also the larger the space inside the test tube, the higher the per cent germination were recognized.

Three seeding rates per Petri dish, germination inhibiting substance of wheat seed coat, and moisture conditions were considered in the Petri dish test (experiment 2). The relationships among the factors considered in the test were not clear when oxygen was not a limiting factor.

Four seeding rates per row, two moisture conditions, and water extracted seed and unextracted seed were considered in the flat test (experiment 3). The higher emergence in the non-preirrigated plot (low moisture) and the lower emergence in the preirrigated plot (high moisture) was obtained in the results except in Kaw; this tendency was significant at the 5 per cent level for Concho. The lower emergence in the higher seeding rate was obtained except for Triumph which showed the higher emergence at the highest seeding rate. The higher emergence in the

water-extracted seed and the lower emergence in the unextracted seed was also obtained except for Kaw. The variation of emergence of the three varieties was not very consistent. The relationships among the factors considered were not significant.

Three seeding rates, water-extracted seed and unextracted seed, and three levels of depth of planting were considered in the pot test (experiment 4). Oxygen as a limiting factor responsible for a decrease of emergence as the seeding rate is increased was a primary consideration in the test. The higher the seeding rate, the lower the per cent emergence; the deeper the depth of planting, the lower the per cent emergence; and, the higher emergence in the extracted seed, the lower emergence in the unextracted seed were obtained in the results. The variations of three varieties with the above respects were highly consistent respectively, though the variations of Kaw in the factors considered were not statistically significant. The interactions among the factors were not statistically significant except the interaction of seed treatment and depth of planting was found significant at the 5 per cent level in Triumph.

Oxygen seems to be one of the most important factors which affects emergence of wheat seed in the scope of this study.

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