EXPERIMENTAL STUDY ON THE EFFECTS OF DIFFERENT PRESSURES AND SOWING DEPTHS ON THE GROWTH CHARACTERISTICS OF OAT UNDER DRY FARMING CONDITIONS

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旱作条件下不同镇压和播深对燕麦生长特性影响的试验研究

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ABSTRACT

In order to comprehensively evaluate the best pressure and sowing depth conditions suitable for oat growth under dry farming, a sowing pressure experimental device was designed. The calculation methods of pressure strength of different types of press wheels were analysed. The experiment calibrated the corresponding counterweight under different suppression strengths. A three-factor and three-level orthogonal experiment was carried out with pressure strength, sowing depth and press wheel type as factors and oat emergence rate, dry matter accumulation at seedling stage and yield as main evaluation indexes. The results showed that the press wheel type had extremely significant effects on oat emergence rate, stem and leaf dry matter quality, total dry matter quality at seedling stage and yield, and had significant effects on root dry matter at seedling stage. The pressure strength had significant effects on the emergence rate and root dry matter quality of oat at seedling stage, and had extremely significant effects on stem and leaf dry matter quality, total dry matter quality at seedling stage and yield. Sowing depth had significant effects on seedling emergence rate, root dry matter quality, stem and leaf dry matter quality, total dry matter quality, and had extremely significant effects on yield. The optimum sowing conditions of oat are as follows: pressure strength is 50 kPa, sowing depth is 5 cm, and press wheel type is conical combined wheel. The results of this study could provide certain references for the design of oat high-yield mechanical sowing technology, oat seeder and press device.

摘 要

为综合评估旱作条件下适于燕麦生长的最佳镇压和播深条件，设计了一种播种镇压试验装置，分析了不同镇压轮型式镇压强度的计算方法，试验标定了不同镇压强度时对应配重的大小，开展了以播种镇压强度、播深、镇压轮型式为因素，以燕麦出苗率、苗期干物质积累量、产量为主要评价指标的三因素三水平正交试验。试验结果表明：镇压轮型式对燕麦出苗率、苗期茎叶干物质量、总干物质量、产量具有极显著影响，对苗期根干物质量具有显著影响；镇压强度对燕麦出苗率、苗期根干物质量具有显著影响，对苗期茎叶干物质量、总干物质量、产量具有极显著影响；播深对燕麦出苗率、苗期根干物质量、茎叶干物质量、总干物质量具有显著影响，对产量具有极显著影响。燕麦最优播种条件为播种镇压强度为50kPa，播种深度为 5cm，镇压轮型式为锥形组合轮。该研究结果可为燕麦高产机械化播种技术、燕麦播种机及镇压装置的设计提供一定参考。

INTRODUCTION

Oat is one-year-old herbaceous plant, belonging to the Gramineae oat genus. It is a kind of food and feed crops *(Hou et al., 2019; Ren et al., 2013)*. Oat has rich nutritional and health value (*Ren et al., 2018; He et al., 2016; Liu et al., 2021*). It is one of the main grain crops in China, which is mainly cultivated in dry farming (rainfed agriculture).

Pressure is one of the important measures to preserve and increase soil moisture in dry farming, and it is also the main step of mechanized sowing. It can improve the seed emergence rate, and thereby ensure the crop yield *(Zuo et al., 2017; Obour et al., 2018; Shahrayini et al., 2018)*. Jia Honglei et al. made an in-depth study on the structure and operating mechanism of the pressure device *(Jia et al., 2015a; Jia et al., 2015b; Jia et al., 2015c; Jia et al.,2018)*. Wang Jingli developed a kind of variable force seedlings roller *(Wang, 2021)*.

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Guo Hui et al. designed a conical squeeze-type coverer, which is a typical device with the functions of soil covering and soil compaction *(Guo et al., 2017)*. Zhao Shuhong and Liu Hongjun et al. designed the compression device suitable for operation in hilly areas. The interaction model between roller and soil under hilly terrain was established *(Zhao et al., 2017; Liu et al., 2018)*. Liu Hongjun et al. designed a press device in mechanical type reducing adhesion and resistance according to the method of terrain machines reducing adhesion and resistance *(Liu et al., 2018)*. Zhang Shilin et al. analysed how different combinations of working parameters of the machine affect such seedbeds constructed with a double-furrow ridge. The interaction between the soil-compact component in the machine and the soil surface was simulated using a three-dimensional finite element model in the ABAQUS software *(Zhang et al., 2020)*. Cui Zhengguo studied the effects of different strength of compaction and sowing depth on emergence rate of maize under the condition of entire returning of maize straw after smashed *(Cui et al., 2018)*. Wang Yanling studied the effects of soil moisture and seeding depth on wheat seedling emergence and growth before winter *(Wang et al., 2014)*. In summary, the current research objects of Chinese scholars are mainly the structural design of the pressure device and the interaction mechanism between the pressure device and the soil. The research on the effects of mechanical repression and sowing depth on crop agronomic characteristics is also limited to major grain crops, such as maize and wheat. The optimum mechanical sowing conditions for oat growth under dry farming conditions were less studied.

In this paper, a pressure experimental device was designed to study the effects of different types of press wheels, pressure strength and sowing depth on the agronomic characteristics of oat, such as emergence rate, dry matter quality of root, stem and leaf at seedling stage and yield under dry farming conditions. The optimum sowing conditions for oat growth were determined in order to provide reference for the mechanized sowing technology of dry farming oats and the design of oat seeder and pressure device.

MATERIALS AND METHODS

Experimental conditions

The experiment was carried out from March 25, 2021 to July 22, 2021 in Shenfeng experimental field of Shanxi Agricultural University, Taigu, Shanxi Province. The experimental soil is clay. Before the experiment, the soil bulk density was 1.27 g/cm, the average soil moisture content was 19.6%, and the pH value was 7.3. The mass fraction of soil organic matter is 1.59%, alkali-hydrolysable nitrogen is 103.6 mg/kg, available phosphorus is 23.7 mg/kg, available potassium is 141.0 mg/kg. The previous crop is buckwheat.

The experimental equipment includes Taihong 404 tractor, 1GKN-200 rotary tiller, V-type ballast, Tianzi scale, steel plate ruler, aluminium box, drying box, shovel, 5TG-85 thresher, dustpan, cleaning screen and so on.

Design of experimental device

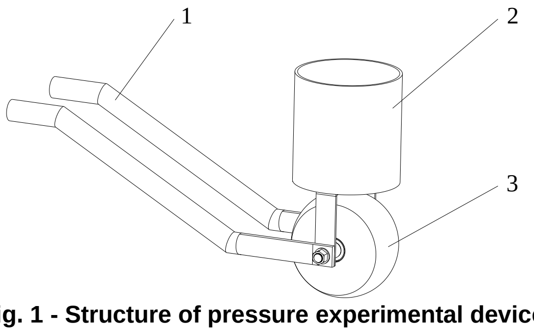

Fig. 1 - Structure of pressure experimental device
1. Handle push rod; 2. Counterweight box; 3. Press wheel

In order to facilitate the replacement of the press wheel and adjust the pressure strength, a pressure experimental device is designed, as shown in figure 1. The experimental device was mainly composed of handle push rod, counterweight box, press wheel and so on. During the experiment, the operator drives the whole experimental device forward through the handle push rod. The counterweight box was always vertical during the movement. The change of pressure conditions can be realized by changing different types of press wheels and changing the counterweight of the counterweight box to meet the requirements of the experimental design.

Selection of experimental factors and factor levels

The purpose of this experiment was to explore whether different pressure and sowing depth under dry farming conditions had an effect on the growth characteristics of oats.

Therefore, the pressure strength, sowing depth and the type of press wheel were selected as the experimental factors, and each factor took 3 levels. The seedling emergence rate, root, stem and leaf dry matter quality and yield of oat were used as evaluation indexes. The orthogonal experimental scheme of three factors and three levels was designed.

The pressure of the press wheel is mainly determined according to the properties of the soil, moisture, density and the requirements of crops. According to the agronomic requirements, it is generally 30~50 kPa *(China Academy of Agricultural Mechanization Sciences, 2007)*. In the experiment, the pressure strength is 30 kPa, 50 kPa and 70 kPa.

According to the requirements of oat cultivation, the suitable sowing depth is 3~5 cm. In the experiment, the sowing depth of oat is 3 cm, 4 cm and 5 cm respectively.

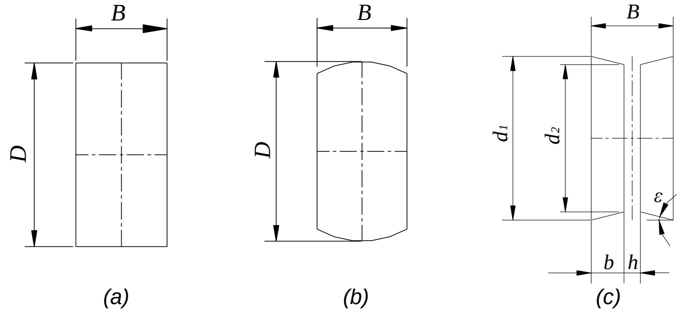

Fig. 2 - Structural of press wheel

a) Plane wheel; b) Convex wheel; c) Conical combined wheel

The press wheel is divided into three types: plane wheel, convex wheel and conical combined wheel, which are most commonly used on the planter. The structure and size are shown in figure 2. In order to ensure the consistency of the pressure experimental conditions, the width and outer diameter of the selected press wheel are equal, and the material is nylon bar (PA66). For planar wheel and convex wheel, the width of crushing wheel B = 150 mm and the outer diameter D = 350 mm. For the conical combination wheel, the major diameter d_1 = 350 mm, the minor diameter d_2 = 310 mm, the horizontal width of a single conical surface b = 65 mm, the distance between the two conical wheels h = 20 mm, and the internal inclination angle ε = 17^0.

The experimental factors and levels are shown in Table 1.

Table 1

Factor-level table of experiment

Levels	Factors		
	Pressure strength [kPa]	Sowing depth [mm]	Press wheel type
1	30	3	plane wheel
2	50	4	convex wheel
3	70	5	conical combined wheel

Determination items and methods

- **Determination of experimental counterweight**

(1) Analysis of interaction between press wheel and soil

The change of the pressure strength in the experiment was realized by changing the counterweight. Therefore, it was necessary to calculate the counterweight required to achieve different pressure strength. The pressure strength is related to the vertical force of the press wheel, grounding area, wheel subsidence and soil characteristics, so it was necessary to analyse the interaction between the press wheel and soil.

The force analysis of the press wheel during the working process is shown in figure 3. In the picture, F is the external force exerted by the operator through the push rod of the handle to drive the press wheel forward. R is the reaction force of the press wheel to the soil, and the angle between the acting force and the vertical direction is β. R_x and R_z denote the horizontal and vertical components of the press wheel subjected to soil reaction, respectively.

Q is the experimental counterweight (including the weight of the pressure device). Z_0 is the maximum subsidence of the press wheel. Z is the amount of soil subsidence at a certain time.

In the vertical direction, the total load of the soil of the press wheelset and the reaction force of the soil to the press wheel R_z act as the acting force and the reaction force against each other, both of which being equal in magnitude and opposite in direction.

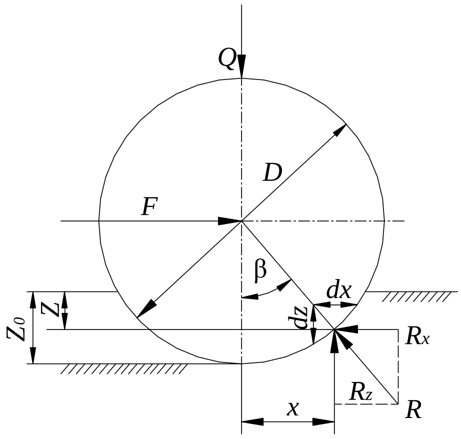

Fig. 3 - Force analysis of press wheel

According to the force analysis, it can be known:

$$Q = \int d\left(R \cdot \cos\beta\right) = \int_0^x p \cdot B \cdot dx \tag{1}$$

where:

- p - the soil compressive strength at depth Z;
- B - the width of the press wheel, mm;
- x - the distance between the point of action of the unit soil force and the centre of the press wheel, mm.

The relationship equation between soil compressive strength p and subsidence Z_0 determined by Bekker empirical formula is *(Geng et al., 2011)*:

$$p = K \cdot Z_0^{\ n} \tag{2}$$

$$K = \frac{k_c}{B} + k_\varphi \tag{3}$$

where:

- K - the soil characteristic parameter, N/cm^2;
- K_c - a coefficient related to soil cohesion;
- K_φ - a coefficient related to soil friction;
- n - the subsidence index.

Simplified by formula (1) (2) (3) and omitted from the higher order *(Geng et al., 2011)* :

$$Z_0 = \left[\frac{3Q}{\left(3-n\right)\left(\frac{k_c}{B}+k_\varphi\right)B\sqrt{D}}\right]^{2/2n+1} \tag{4}$$

In order to facilitate the calculation, when the subsidence of the wheel is small, the non-rigid pavement bears the load, and the calculation of the subsidence can be simplified as follows *(Jia et al., 2015)*:

$$Z_0 = \frac{6Q}{5KBD^{1/2}} \tag{5}$$

$$K = \alpha_0\left(1+0.27B\right) \tag{6}$$

where:

- α_0 - a parameter related to soil properties.

For the clay soil that has just loosened, the related parameter of soil characteristics is α_0 = 1.01. K = 5.1005 N/cm^2 can be calculated.

(2) Determination of grounding area of press wheel

When the rigid wheel is walking on the non-rigid road, its grounding area can be regarded as a rectangle. The area can be expressed by the product of the width of the rigid wheel and the radial contact arc length. The ground contact diagram of the press wheel is shown in figure 4.

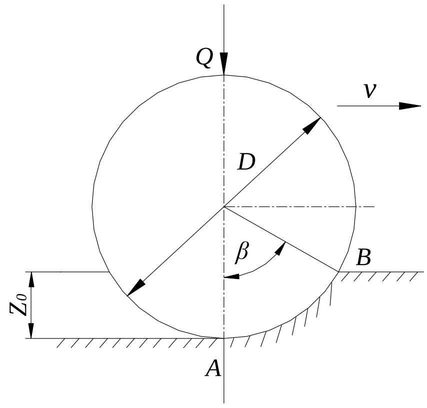

Fig. 4 - Contact between press wheel and ground

① Plane wheel

$$\begin{cases} S_1 = B \cdot l_{AB} = \dfrac{B \cdot \pi \beta D}{360^0} \\ \cos\beta = \dfrac{D-2Z_0}{D} \end{cases} \tag{7}$$

where:

- S_1 - the grounding area of the planar wheel, cm^2;
- L_{AB} - the arc length of contact between the plane wheel and the ground, cm;
- β - the contact angle, (°).

Simplified:

$$S_1 = \frac{\pi BD}{360^0}\cos^{-1}\left(\frac{D-2Z_0}{D}\right) \tag{8}$$

② Convex wheel

For the convenience of calculation, the convex wheel is approximately spherical, and then:

$$S_2 = \frac{\pi D^2}{720^0}\cos^{-1}\left(\frac{D-2Z_0}{D}\right) \tag{9}$$

where:

- S- the grounding area of the convex wheel, cm^2.

③ Conical combined wheel

In this paper, because of the symmetry of the structure and the conical structure characteristics of the left and right press wheel, the press wheel selected is similar to the reference [15]. Combined with figure 2 and referring to the calculation method in reference [15], the grounding area of a single conical wheel of the conical combination wheel is:

$$\begin{cases} S_3 = \dfrac{\pi bd}{360^0}\cos^{-1}\left(\dfrac{d-2Z_0}{d}\right) \\ d = \dfrac{d_1+d_2}{2} \end{cases} \tag{10}$$

where:

- S_3 - the ground area of conical combination wheel, cm^2;
- b- the horizontal width of a single conical surface, 65 mm;
- d - calculate the diameter of the grounding area of the contact area, 330 mm.

(3) Determination of pressure strength

Ignoring the flow of soil to both sides under the press wheel, the soil at the upper edge and centre of the ground is pressed to the same extent. In this way, the vertical force acting on the ground of the press wheel can be approximately considered as a uniform distribution on the rectangular surface. When the pressure on the soil is ρ, then:

$$\begin{cases} \rho_1 = \dfrac{Q}{S_1} = \dfrac{300^0 KZ_0}{\pi D^{1/2} \cos^{-1}\left(\dfrac{D-2Z_0}{D}\right)} \\ \rho_2 = \dfrac{Q}{S_2} = \dfrac{600^0 KBZ_0}{\pi D^{3/2} \cos^{-1}\left(\dfrac{D-2Z_0}{D}\right)} \\ \rho_3 = \dfrac{Q\cos\varepsilon}{2S_3} = \dfrac{150^0 KBZ_0 \cos\varepsilon}{\pi b d^{1/2} \cos^{-1}\left(\dfrac{d-2Z_0}{d}\right)} \end{cases} \tag{11}$$

where: - ρ_1 - the soil pressure of the plane wheelset, kPa;

- ρ_2 - the soil pressure of the convex wheelset, kPa;
- ρ_3 - the soil pressure of conical combined wheelset, kPa.

According to the selection of experimental factors, the pressure strength ρ is 30 kPa, 50 kPa and 70 kPa respectively. Take K = 5.1005, D = 350 mm, B = 150 mm, b = 65 mm, d = 330 mm, ε = 17^0 into the formula calculation. The value of the subsidence amount Z_0 of the press wheel is shown in Table 2.

(4) Determination of experimental counterweight.

According to the formula (5) (11), it is known that the subsidence amount Z_0 of the press wheel is positively related to the counterweight Q, and the pressure strength is related to Z_0. For the manoeuvrability of the experiment, it was necessary to study the relationship between counterweight Q and subsidence Z_0, and the subsidence calibration experiment of the press wheel was carried out. It was assumed that under the same soil condition and the same counterweight, the F value imposed by the operator in the experimental process is equal to that in the calibration process. During calibration, the weighing Q was weighed by an electronic scale, and the subsidence of the press wheel Z_0 was measured with a tape measure. Where Q is the gravity load, which is expressed by the product of mass and gravity acceleration. In order to increase the accuracy of the calibration curve, the average value of soil subsidence was measured 5 times for each additional 10 kg in the calibration process. In this process, the press wheel moves at a uniform speed as far as possible, and the walking distance was not less than 3 m each time. The experimental conditions were the same as those in section 1.1.

The curve of soil subsidence Z_0 versus counterweight Q was obtained by Excel fitting, as shown in figure 5.

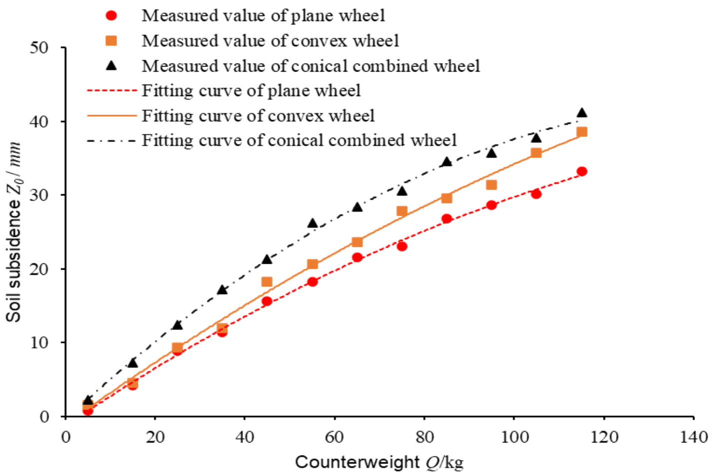

Fig. 5 - Calibration curve

The fitting quadratic equation (12). R^2 is greater than 0.99, and the fitting effect is good:

$$\begin{cases} y_1 = -0.001x_1^2 + 0.4111x_1 - 1.292 \\ y_2 = -0.0009x_2^2 + 0.4386x_2 - 1.1359 \\ y_3 = -0.0018x_3^2 + 0.5629x_3 - 0.4237 \end{cases} \quad (12)$$

where:

- x_1 - counterweight corresponding to the soil subsidence of plane wheel, kg;
- x_2 - counterweight corresponding to the soil subsidence of convex wheel, kg;
- x_3 - counterweight corresponding to the soil subsidence of conical combined wheel, kg;
- y_1 - soil subsidence of plane wheel, mm;
- y_2 - soil subsidence of convex wheel, mm;
- y_3 - soil subsidence of conical combined wheel, mm.

Based on the fitting function relationship, the value of Z_0 is brought into Formula (12), and the value of counterweight Q can be obtained, as shown in Table 2.

Table 2

Calculation result

Press wheel type	**Pressure strength** ρ [kPa]	**Soil subsidence** Z_0 [mm]	**Counterweight** **Q** [kg]
plane wheel	30	5.0	15.95
	50	14.0	41.45
	70	27.9	91.14
convex wheel	30	6.8	18.82
	50	19.2	51.89
	70	38.3	118.94
conical combined wheel	30	4.1	8.25
	50	11.5	22.85
	70	22.8	48.91

- **Determination of seedling emergence rate**

After 15 days of oat sowing, the data of oat emergence in each experimental plot were counted. The emergence rate was recorded at the same time every two days. When the emergence rate does not increase for 3 times in a row, it is regarded as the end of emergence. The final emergence rate is used as the final evaluation data of the sowing plot experiment. The emergence rate was calculated according to formula (13).

$$\text{Emergence rate} = \frac{\text{Emergence number}}{500} \times 100\% \quad (13)$$

- **Determination of dry matter quality at seedling stage**

In the oat seedling stage, five clusters of whole oats growing in each plot were selected by five-point method. In order to ensure the integrity of the root system of oats, the samples were shovelled with soil. After washing the whole oat plant with soil with water, 5 groups of oat plants were randomly selected in the same experiment, with 10 plants in each group. After separating the roots and stems and leaves with scissors, the roots and stems and leaves were dried respectively. The dry matter quality of root and stem and leaf were recorded, and the average value was taken as the evaluation data of the experiment. The experimental process is shown in figure 6.

(a) (b)

Fig. 6 - Experimental process

a) Sampling; b) Drying

- **Determination of yield**

First, the harvest was carried out in turn according to the order of the plots, and the marks were made. The oat plants in the area were cut down, bundled and transported to the laboratory of College of Agricultural Engineering, Shanxi Agricultural University by artificial harvesting. Then, the 5TG-85 threshing machine was used for threshing, and the clean oat seeds were obtained by manual cleaning and weighed. Finally, the yield of the plot is converted into the yield per hectare. The determination process is shown in figure 7. The moisture content of oat grain after harvest was measured to be 15.42% by drying method.

Fig. 7 - Yield determination

RESULTS

Pre-broadcast processing

After rotary tillage with 1GKN-200 rotary tillage machine, the surface soil was relatively weak. In order to ensure the accuracy of the experiment, the V-type ballast was used to firm the soil before sowing to ensure that the surface was smooth and the soil was fine. The working process before sowing is shown in Fig. 8.

Fig. 8 - Working process before sowing

Sowing experiment

Sowing experiment selected plot sowing method, plot area is 2 m × 5 m = 10 m^2. In order to facilitate data acquisition, the length direction interval between cells is 1 m. The oat variety Pinyan No.4 was selected in the experiment. The average moisture content of seeds was 9.46 %, and the average 1000-grain weight was 25 g. According to the agronomic requirements of oats, 6 rows were sown in each plot, and the sowing amount was calculated as 150 kg/hm^2, and the sowing number per row was 500 seeds. In order to ensure the accuracy of the experimental data of seedling emergence rate and reduce the workload, two rows were selected to sow 500 seeds in each plot, and the other rows were calculated by weighing according to the sowing amount per hectare. When sowing, mechanical trenching is used. The sowing depth is controlled by adjusting the depth of the opener. After sowing, it was pressed according to the experimental design.

Experimental design and results

The experimental design and results are shown in Table 3. In the table, A, B and C are the coding values of pressure strength, sowing depth and press wheel type, respectively. The results of variance and range analysis are shown in Table 4.

Experimental plan and results **Table 3**

Groups	Factors			Emergence rate [%]	Dry matter accumulation of ten seedlings at Seedling Stage [g]			Yield [kg/hm²]
	A	*B*	*C*		root [g]	stem and leaf [g]	total [g]	
1	1	1	1	74.07	0.57	4.67	5.24	1930.80
2	1	2	2	79.76	1.34	7.58	8.92	2194.35
3	1	3	3	82.62	1.64	8.31	9.95	2296.05
4	2	1	2	80.37	1.72	9.06	10.78	2390.85
5	2	2	3	85.23	2.18	10.87	13.05	2531.25
6	2	3	1	81.17	1.43	8.16	9.59	2376.30
7	3	1	3	78.71	1.26	7.45	8.71	2149.20
8	3	2	1	75.8	0.88	6.42	7.30	2074.95
9	3	3	2	81.03	1.48	8.29	9.77	2261.10

Results of variance and range analysis **Table 4**

Index	Source	SS	DF	MS	*F*	*P*	k_1	k_2	k_3	*R*	Optimization level	Optimal combination
Emergence rate	*A*	25.94	2	12.97	65.39	0.015*	78.82	82.26	78.51	3.74	A_2	$A_2B_3C_3$
	B	23.40	2	11.71	59.04	0.017*	77.72	80.26	81.61	3.89	B_3	
	C	41.38	2	20.69	104.32	0.009**	77.01	80.39	82.19	5.17	C_3	
	Residual	0.397	2	0.198								
	Total	91.14	8									
Root dry matter mass	*A*	0.68	2	0.34	72.42	0.014*	1.18	1.78	1.21	0.59	A_2	$A_2B_3C_3$
	B	0.19	2	0.10	20.72	0.046*	1.18	1.47	1.52	0.33	B_3	
	C	0.88	2	0.44	93.67	0.011*	0.96	1.51	1.69	0.73	C_3	
	Residual	.009	2	0.005								
	Total	1.76	8									
Stem and leaf dry matter mass	*A*	10.49	2	5.25	122.44	0.008**	6.85	9.36	7.39	2.51	A_2	$A_2B_2C_3$
	B	2.94	2	1.47	34.29	0.028*	7.06	8.29	8.25	1.23	B_2	
	C	9.96	2	4.98	116.20	0.009**	6.42	8.31	8.88	2.46	C_3	
	Residual	0.086	2	0.043								
	Total	23.47	8									
Total dry matter mass	*A*	16.43	2	8.21	108.49	0.009**	8.04	11.14	8.59	3.10	A_2	$A_2B_3C_3$
	B	4.62	2	2.31	30.52	0.032*	8.24	9.76	9.77	1.53	B_3	
	C	16.74	2	8.37	110.58	0.009**	7.38	9.82	10.57	3.19	C_3	
	Residual	0.151	2	0.076								
	Total	37.94	8									
yield	*A*	708.54	2	354.27	438.43	0.002**	142.69	162.19	144.12	19.49	A_2	$A_2B_3C_3$
	B	168.08	2	84.04	104.01	0.010**	143.80	151.12	154.08	10.28	B_3	
	C	289.31	2	144.66	179.02	0.006**	141.82	152.14	155.03	13.21	C_3	
	Residual	1.616	2	0.808								
	Total	1167.55	8									

*Note: * indicates significant difference (0.01 < P < 0.05), ** indicates extremely significant difference (P < 0.01)*

It can be seen from Table 4 that the type of press wheel has extremely significant effects on the emergence rate of oat, and pressure strength and sowing depth have significant effects on the emergence rate of oat. The order of influence from large to small is press wheel type, sowing depth, pressure strength, and the optimal combination is $A_2B_3C_3$.

Pressure strength, sowing depth and press wheel type have significant effects on the dry matter accumulation of oat roots at seedling stage, and the order of influence from large to small is press wheel type, pressure strength and sowing depth, and the optimal combination was $A_2B_3C_3$. Pressure strength and the type of press wheel have extremely significant effects on the dry matter accumulation of stems and leaves of oats at seedling stage. Sowing depth has significant effects on the dry matter accumulation of stems and leaves of oats at seedling stage. The order of influence from large to small is pressure strength, press wheel type, sowing depth, and the optimal combination is $A_2B_2C_3$. Pressure strength and the type of press wheel have extremely significant effects on the total dry matter accumulation of oats at seedling stage, and the sowing depth has significant effects on the total dry matter accumulation of oats at seedling stage. The order of influence from large to small is press wheel type, pressure strength, sowing depth, and the optimal combination is $A_2B_3C_3$.

Pressure strength, sowing depth and press wheel type have extremely significant effects on oat yield. The order of influence from large to small is pressure strength, press wheel type, sowing depth, and the optimal combination is $A_2B_3C_3$.

Discussion

Effects of different pressure on growth characteristics of oats

Shi Zuliang et al. showed that post-sowing pressure could significantly increase the number of wheat seedlings by 31.8% and increased the grain yield of wheat *(Shi et al., 2015)*. Shen Guanyu et al. showed that under the same ploughing and raking factors, after press treatment, the emergence rate of wheat increased by 0.06% to 8.3%, and the yield increased by 1.5% to 9.6% *(Shen et al., 2019)*.

Jia Chunlin et al. showed that under the condition of returning full amount of corn straw to the field, pressure extremely significant affected the emergence rate of wheat, with a force of 23.48% *(Jia et al., 2010)*.

Liu Hongjun studied that the primary and secondary order of the factors affecting the performance of the pressure device were press wheel type, pressure strength and operation speed, and press wheel type had significant effects on the emergence rate of maize in the hilly and mountainous areas of Northeast China *(Liu, 2019)*. The results of this experiment showed that the type and strength of press wheel had significant effects on the emergence rate, dry matter accumulation at seedling stage and yield of oats, which was consistent with the above conclusions.

As far as the type of press wheel is concerned, the growth characteristics of oats with conical combined wheel (C_3) are the best. This may be because, the soil on both sides of the seedling belt is compacted when the conical combined wheel is working, which played the role of storing water and preserving soil moisture, and the middle part is relatively soft. It is beneficial to the emergence, growth and development of seeds. Under the comprehensive action, the conical combined wheel showed the best pressure effect.

As far as pressure strength, 50kPa (A_2) is the optimal level, which may be because too much or too small pressure strength will affect soil porosity and moisture content, thus affecting the growth of oats. This is consistent with the results of *Wang X., (2020)*.

As far as the primary and secondary factors are concerned, the type of press wheel has the greatest influence on the emergence rate, and the type and strength of press wheel in other aspects have a greater influence than sowing depth.

According to the comprehensive comparison, the effect of pressure on the growth of oat was greater than that of sowing depth under dry farming. This may be because under the same conditions, pressure strength and press wheel type together determine the effect of the pressure device. Pressure can improve soil moisture, store water and preserve soil moisture, improve seed germination and growth environment, enhance the contact between seeds and soil, promote seed germination and seedling emergence, and increase the rate of seedling emergence. The better the pressure, the better the oats grow. This is consistent with the research results in *Liu H.J., Han J.Y., Chen J.Q., et al, (2018)*.

Effect of different sowing depth on the growth characteristics of oats

Zheng Ting et al. showed that sowing depth had a great effect on wheat seedling emergence. The basic seedlings under 5 cm sowing depth were 16.3% higher than those under 2 cm sowing depth, reaching a very significant level. When the sowing depth was 5 cm, the number of tillers per plant and the highest seedling were the best. The effect of sowing depth on root activity reached a very significant level, and the root activity was the highest when sowing depth was 5 cm. The effect of sowing depth on dry matter quality reached a significant level *(Zheng et al., 2011)*.

Zhao Lingtian et al. thought that the sowing depth of wheat was 5 cm, which generated low seed exposure rate and relatively high seedling emergence rate *(Zhao et al., 2021)*.

Xu Hongjun et al. showed that the emergence rate of wheat was affected by sowing depth, seed quality, soil moisture, soil preparation quality and other factors. Under the condition of suitable soil moisture, the suitable sowing depth of wheat is 3 ~ 5 cm. For the plots with sufficient soil moisture, poor soil fertility and late sowing, the suitable sowing depth is about 3 cm. For the plots with poor soil moisture and fertile soil fertility, the suitable sowing depth is 4 ~ 5 cm *(Xu et al., 1999)*.

In this paper, it is concluded that sowing depth has significant effects on seedling emergence rate, root dry matter accumulation, stem and leaf dry matter accumulation and total dry matter accumulation at seedling stage and has extremely significant effects on the yield of oats. In terms of sowing depth, when the sowing depth is too shallow, the soil moisture content is low, which is not conducive to oat seed germination. After the press, due to the squeezing effect of the press wheel on the soil, the depth of the soil cover is shallow, which will cause some seeds to be exposed on the surface and it is difficult to germinate. In addition, when the sowing depth is too shallow, the soil environment of seed growth after germination is relatively poor. When the soil layer is dry, it is difficult to obtain sufficient nutrients for growth and development. This leads to the thinness of seedlings, and even the phenomenon of yellow and dead seedlings. As a result, the seedling emergence rate decreased, the dry matter accumulation in the seedling stage decreased, and then led to the reduction of yield. When sowing too deep, it is not conducive to the emergence of seeds. As the oat seed consumes a lot of nutrients in the process of soil breaking, it will also make the seed performance slenderer after emergence, reduce the dry matter accumulation at the seedling stage, and finally reduce the yield. Therefore, sowing too deep or too shallow is not conducive to the growth and development of oats.

In conclusion, the optimum sowing condition of oats are $A_2B_3C_3$. The pressure strength is 50 kPa, the sowing depth is 5 cm, the press wheel type is conical combination wheel.

In addition, the results of the above experiments are only one year of field trials, and a large number of field trials for many years are needed to track and demonstrate.

CONCLUSIONS

(1) A pressure experimental device was designed. The calculation methods of the pressure strength of three different types of press wheels, namely plane wheel, convex wheel and conical combined wheel, were analysed. Through the field calibration experiment, the counterweight was determined when the pressure strength was 30 kPa, 50 kPa and 70 kPa.

(2) The effects of various experimental factors on the growth characteristics of oat were tracked and analysed by taking the pressure strength, sowing depth and press wheel type as experimental factors, and the emergence rate, dry matter quality and yield of oats as evaluation indexes. The results showed that the press wheel type had extremely significant effects on the emergence rate, stem and leaf dry matter quality, total dry matter quality at seedling stage and yield of oat, and had significant effects on root dry matter quality at seedling stage. The pressure strength had significant effects on the emergence rate and root dry matter quality of oat at seedling stage, and had extremely significant effects on stem and leaf dry matter quality, total dry matter quality at seedling stage and yield. The sowing depth had significant effects on seedling emergence rate, root dry matter quality, stem and leaf dry matter quality, total dry matter quality, and extremely significant effects on yield of oats. The optimum sowing conditions of oats are as follows: pressure strength is 50 kPa, sowing depth is 5 cm, and press wheel type is conical combined wheel.

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