DEVELOPMENT AND EXPERIMENTS OF CHAIN DRAGGING GARLIC FILM BREAKER

Tianhua LI[1], Yukang YAO[2], Mingxing CHENG[3], Guoying SHI[4]*, Jialin HOU[5]

Aiming at the problems of low manual work efficiency and high labor intensity of garlic film breaking, a chain dragging method of film-breaking is proposed, garlic buds penetrate the film under the combined action of the chain and film. In order to optimize the film-breaking performance and improve the film-breaking efficiency, the garlic seedling film-breaking machine was used to conduct field experiments with different chains and operating speeds. Through analysis of the experiment data by HEML and Prism data processing software, the optimal chain was an 8 mm diameter stainless-steel short-ring chain; the optimal operating speed was 2.5 m/s. Under this condition, the film breaking ratio and damage ratio of garlic buds were 98% and 9%, and the relative damage ratio and perfect ratio were 9.1% and 89%. Compared with the manual film breaking, the machine's film breaking ratio of garlic buds increased by 10.5%, but the damage ratio of garlic buds was the same; the machine's maximum operating efficiency was 5.4 hm²/h, about 2.5 times of the manual.

Keywords: Garlic bud, Film breaker, Chain, Visual aid, Field experiment

1. Introduction

Garlic and its products are traditional seasoning foods that people like, and they also have good therapeutic and medicinal value[1,2,3]. At present, the mechanization research of garlic in sowing and harvesting has entered a stage of rapid development [4,5]. However, garlic film breaking is still mainly manual, the related film breaking machine research is still in the blank stage. Garlic is usually covered with plastic film after being sowed, and most of the garlic buds penetrate the film with the help of external force. For garlic with normal broken film, garlic bud is upright and can continue to grow normally; for garlic without broken film, garlic bud is curved under the film, which affects its normal growth [6].

The film breaking operation begins with the garlic buds growing to 1-2 cm high. The traditional methods of garlic film breaking are mainly included manual

[1] Prof., College of Mechanical and Electronic Engineering, Shandong Agricultural University, China, e-mail: lth5460@163.com
[2] Master., College of Mechanical and Electronic Engineering, Shandong Agricultural University, China, e-mail: yaoyukang@163.com
[3] Master., College of Mechanical and Electronic Engineering, Shandong Agricultural University, China, e-mail: mxcheng0912@163.com
[4] College of Mechanical and Electronic Engineering, Shandong Agricultural University, China, e-mail: sgy509@sdau.edu.cn *Corresponding Author
[5] Prof., College of Mechanical and Electronic Engineering, Shandong Agricultural University, China, e-mail: jlhou@sdau.edu.cn

hook film, manual flapping film, and manual pull film. Manual hook film is broken film with an iron hook, and then take out garlic buds. This kind of film breaking mode has a large amount of work and high strength, Moreover, the film has a large tear, which affects the insulation and moisturizing effect; Manual flapping film is to pat on the film with a broom, and then help the garlic bud to break the film, the damage rate of garlic bud was higher; Manual pull film is the sack, chain tiled on the film, and then manual pull to achieve the purpose of breaking garlic bud film. The film breaking efficiency is high, but it has certain damage to garlic buds. Wang et al. used wet felt to break the film of garlic bud. The efficiency of breaking the film was higher than other manual methods, but the labor intensity and the damage percentage of garlic bud were higher [7]. Yang et al. studied the potato seedling emergence cultivation technology with natural broken film[8]. Chen et al. studied the yam seedling emergence cultivation technology with simplified and free broken film[9], and Zhang et al. studied the konjac seedling emergence cultivation technology with natural broken film covered with plastic film [10]. The common points of the above three studies are as follows: after the planting and mulching of crops, the link of covering the soil on the film was added. With the help of the self-weight of the soil, the mulching film was in close contact with the soil under the film. When the crop buds grow upward, they will automatically break the mulching film and emerge. However, the covering of soil on the film affects the light transmittance and heat preservation of the film. Liu et al. proposed an automatic positioning method for tobacco film breaking. The tobacco film was first positioned and then broken, which improved the efficiency of film breaking to a certain extent, but the accuracy of positioning still needed to be improved[11].

This paper presents a chain towed garlic seedling film breaker based on visual assistance and remote control. The whole machine is mainly composed of crawler chassis, film breaking device, remote-control device. The crawler chassis reduces the impact of compaction and improves ground leveling consistency [12]. Film breaking device can realize chain retraction and release, and adjust the film breaking range. Remote control can be realized through visual assistance to control the whole machine, chain retraction, and pan-tilt [13,14]. Moreover, eight different chains and five different speed combinations were combined and field trials were carried out. Through the analysis of membrane rupture effect and experimental data, the optimal membrane rupture conditions and corresponding parameters were determined.

2. Material and methods

2.1 Garlic seedling film breaker

As shown in figure 1, the garlic film breaker is mainly constituted of crawler chassis, foldable film breaking device, visual-aid device, remote-control device, and control system. The structure parameters of the whole machine are shown in Table 1.

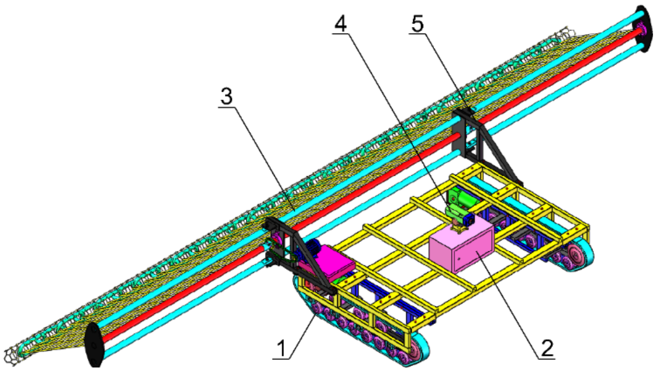


Fig. 1. Structure schematic diagram of garlic film breaker. 1 = Crawler chassis, 2 = Control box, 3 = Foldable film-broken device, 4 = Camera, 5 = Supporting frame.

Table 1

Structural parameters of garlic film breaker

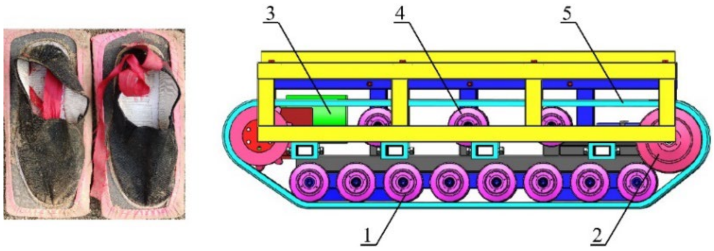
Item	Parameter
Total weight/kg	120
Overall dimensions (length×width×high)/(mm×mm×mm)	6000×1500×780
Driving motor power/W	500
Stepper motor power/W	200
Maximum forward speed/(m/s)	5
Crawler width/mm	85
Maximum film-broken/mm	6000
Folding frame length/mm	2000
Maximum work borders	3

2.2 Working principle

Before film breaking, unfold the folding part of the film breaking device fixed on the chassis, control the rolling shaft connected with the stepping motor to rotate, and slowly put down the yarn mesh and the chain wrapped with cotton cloth until it is tiled on the plastic film. The crawler chassis runs along the gap between two adjacent films, and the chain drags on the film. The downward pressure of the film increases with the approach of the chain, and the upward support force of garlic buds also increases. When the supporting force is greater than the strength limit of the plastic film, the garlic bud breaks through the film. When the chain passes through the contact point between the garlic bud and the film, the film around the garlic bud also slides down to the base of the garlic bud under the action of the chain and is fixed at the position in contact with the soil. The camera obtains the vehicle condition information in real time and transmits it to the mobile app. The mobile phone can flexibly adjust the running direction of the machine to avoid pressing garlic buds; After the film breaking work is completed, control the rolling shaft to rotate in the opposite direction, slowly roll up the yarn mesh, and finally retract the folding frame, and the machine returns to the starting state. According to the actual planting range, the film breaking requirements of one to three rows of garlic buds can be met by folding or unfolding the folding frame.

2.3 Crawler chassis

The soil on which garlic is sown was muddy and soft after irrigation and full penetration, an ordinary wheeled walking device was prone to appear the phenomenon of sinking and sliding when operating in the field. Garlic farmers use special shoes for walking in the field during artificial membrane breaking, as shown in figure 2(a), the sole of the foam material is easily deformed, and water is easy to seep into the shoes. Crawler chassis is designed to improve the passability of the whole machine, as shown in figure 2(b), The crawler chassis is mainly composed of driving wheels, guide wheels, load-bearing wheels, crawler belts, and DC motors.



(a) (b)

Fig. 2. Walking devices. (a) Manual film-breaking field walking shoes. (b) Crawler chassis.
1 = Thrust wheel, 2 = Driving wheel, 3 = DC motor, 4 = Towing wheel, 5 = Crawler belt

2.4 Foldable film breaking device

Foldable film breaking device is mainly composed of the rolling shaft, folding frame, support frame, universal joint, universal centripetal, stepper motor, transmission chain, chain, gauze, and so on. The connection between the folding frame and the rolling shaft is presented in figure 3(a). The rolling shaft and the folding frame were divided into three sections, each of which was two meters long, the three sections rolling shaft was connected together by the universal joint and the universal centripetal, and was fixed in the middle of the upper and lower folding frame by combining with the bearing. The rotation of the rolling shaft can realize the winding up and lowering of the film breaking mechanism. Through the retraction and placement of the folding frame, the application range of the machine is improved. The film-breaking institution is shown in figure 3(b), one end of the gauze is wrapped with a chain and the outside is wrapped with cotton cloth; The other end is fixed on the rolling shaft. It can meet the requirements of efficient film breaking and reducing the damage of film and garlic bud.

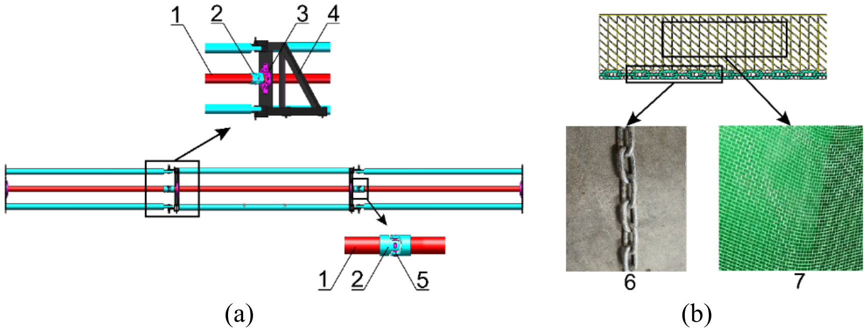


Fig. 3. Foldable film breaking device. (a) Folding frame. (b) Film-breaking institution.
1 = Rolling shaft, 2 = Universal joint, 3 = Bearing, 4 = Support frame,
5 = Universal centripetal, 6 = Chain, 7 = Gauze.

2.5 Control system

As shown in figure 4, The control system of the garlic film breaker is mainly constituted of a power module, WIFI module, visual-aid device, remote-control device, STM32F103 processor, brushless motor driver, stepper motor, and DC motor. The camera in the visual aid device is fixedly installed on the pan-tilt and communicates with the mobile phone through the WiFi module. The mobile app can adjust the horizontal and vertical directions of the camera, so as to realize the three-dimensional monitoring of operation conditions. Through the remote control device, instructions such as steering, turning head, gauze collection and playback can be sent to the processor to complete the film breaking operation. Both visual aids and remote control devices adopt mature commercial modules with high reliability and low price.

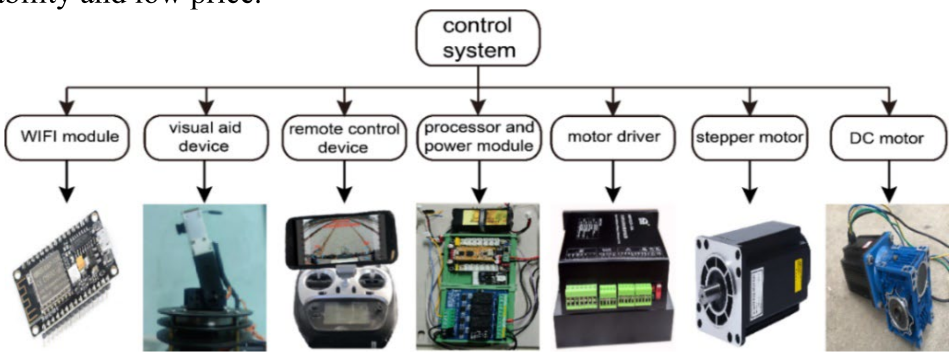


Fig. 4. Structure composition of control system

2.6 Field experiment

2.6.1 Experiment conditions and material

The field experiment was conducted in Dajiang village, Jinxiang County, Jining City, Shandong Province. The local planting pattern of garlic is as follows: Before sowing, deep plough and fine rake the soil to ensure that the terrain is flat and the clods are finely broken and loose. Three adjacent films are laid between the two ridges, each of which is about 2 m wide and 50m long, and the gap between the two adjacent films is about 120 mm. Garlic plant spacing is 10-12 mm, row spacing is 18-20 mm. The film used in the experiment is the breathable mulch film used by garlic farmers. The thickness of this type of film is only 0.004mm, with good light transmittance and long service life. After sowing, flood irrigation, and then plastic film mulching. The film breaking of garlic is generally 3-5 days after watering and film covering, and some garlic buds grow to 1-2 cm high. At this time, the bud tip remains closed, the leaves have not yet expanded, the top is sharp and hard, and the ground is flat without large clods, so it is easy to pierce the film.

The film-breaking mode of chain dragging is susceptible to factors such as chain type, chain weight, and machine forward speed. Chain type is divided into stainless steel long ring and stainless steel short ring. Too light chain will reduce the film breaking ratio of garlic buds, too heavy chain will increase the damage percentage of garlic bud; The faster the machine forward speed, the higher the garlic bud damage percentage, the greater the probability of film damage. In order to determine the reasonable chain form, the chain with different parameters is selected for comparative test. The parameters of the chain are shown in Table 2, and the physical diagram of the chain is shown in Figure 5. Among them, 10mm-L represents a stainless-steel long-ring chain with a diameter of 10mm, 10mm-S represents a stainless-steel short-ring chain with a diameter of 10mm. Referring to the manual breaking speed (1 m/s-1.5 m/s), the forward speed of the experiment is set to 1 m/s, 1.5 m/s, 2 m/s, 2.5 m/s, 3 m/s.

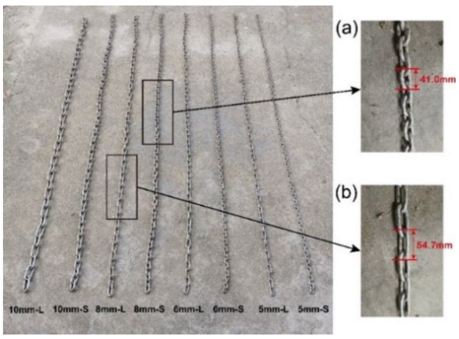


Fig. 5. Physical diagram of test chain. (a) 8mm stainless-steel short-ring chain. (b) 8mm stainless-steel long-ring chain

Table 2

Test chain model (stainless-steel)

Specification	Shape	Diameter (mm)	External width(mm)	External length(mm)	Chain weight (kg)
5mm-L	Long-ring	5	18.5	38.7	0.88
6mm-L	Long-ring	6	21.5	43.3	1.30
8mm-L	Long-ring	8	27.8	54.7	2.36
10mm-L	Long-ring	10	36.3	61.5	3.90
5mm-S	Short-ring	5	18	28.8	1.00
6mm-S	Short-ring	6	20.2	30	1.60
8mm-S	Short-ring	8	25.7	41	2.80
10mm-S	Short-ring	10	32	48	4.60

2.6.2 Experiment method

In the experiment, eight different types of chains are selected and fixed at the end of the gauze respectively. Each chain is 2 meters long and each three chains form a group. The length of each border was 50 m, which was divided into five sections corresponding to five different forward speeds and marked, and the film breaking test was carried out in turn. The film breaking test lasted for 4 days, and a round trip test was completed before 8 : 00 every morning. The film breaking conditions under different chain types and speeds were counted. Statistics 200 garlic buds of different chains under the same condition each time, calculate the number of garlic buds breaking through the film and the number of damage such as bending and breaking and get the film breaking ratio, damage ratio, relative damage ratio, and perfectness ratio of garlic buds. Repeat the test three times in different test border, take the average as the final result. As shown in figure 6, The label in the figure is the garlic buds damaged during the film breaking process, and the rest are the garlic buds with normal film breaking.

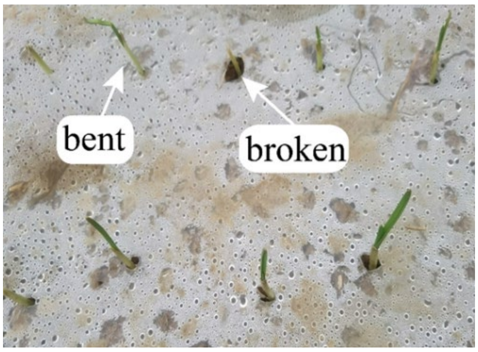


Fig. 6. Statistical sample chart of garlic bud breaking effect

3. Results and discussion

The number of garlic buds piercing the film are recorded as m, and the number of garlic buds damaged are recorded as n. Using m and n to calculate the required data indicators, Q1 is the film breaking ratio of garlic bud, Q2 is the damage ratio of garlic bud, Q3 is the relative damage ratio of garlic bud, Q4 is the perfectness ratio of garlic bud.

$$Q1 = m/200 \tag{1}$$

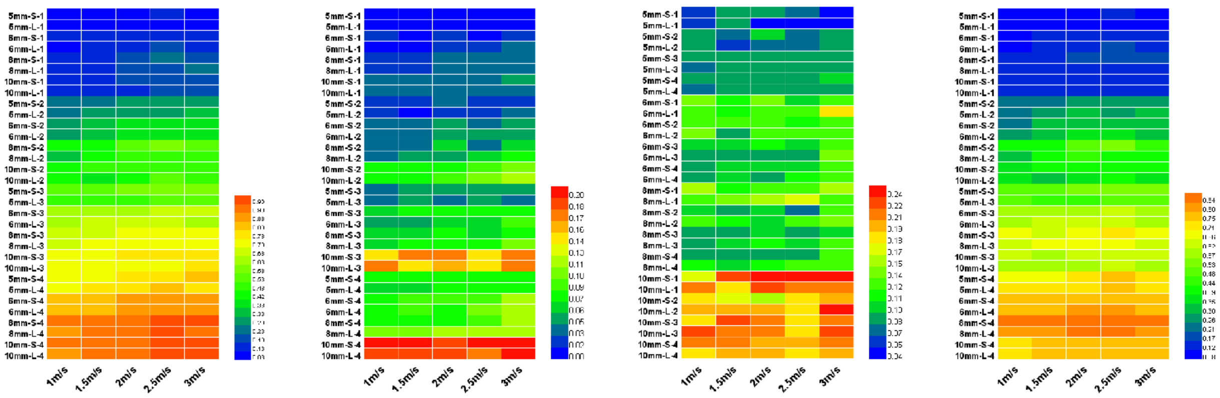
$$Q2 = n/200 \tag{2}$$

$$Q3 = n/m \tag{3}$$

$$Q4 = Q1 - Q2 = (\mathrm{m} - \mathrm{n})/200 \tag{4}$$

3.1 Overall data analysis of film breaking process

The data indexes under different test conditions were analyzed by HEML data processing software, and the corresponding heat maps were made. The colors of the bar shown to the right of the heat map varied from blue to red representing the relative levels from low to high. As shown in figure 7, among them, 5mm-S-1 represents the film-breaking situation of the 5mm short-ring chain on the first day, and 5mm-L-1 represents the film-breaking situation of the 5mm long-ring chain on the first day.



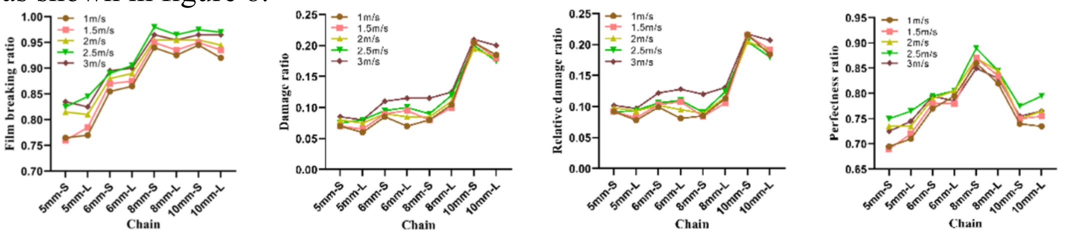
(a) (b) (c) (d)

Fig. 7. The heat-map changes corresponding to different data processing methods of different chains and different speeds in a film breaking cycle. (a-d) show the heat-map changes of the relative levels of Q1, Q2, Q3, and Q4 during the film-breaking process respectively.

Figure 7(a) shows that the broken film ratio increases with the increase of broken film days. The broken film ratio of 8 mm and 10 mm chains is higher than that of other chains in the same broken film days, and the broken film ratio is also higher than other speeds at 2.5 m/s and 3 m/s speeds. Figure 7(b) is the heat map of damage ratio, the damage ratio of garlic buds also increases with the increase of the number of days of film breaking, in which the damage ratio of garlic buds of 10 mm chain on each film breaking day is higher than that of other chains, and the damage ratio of garlic buds of other chains on each film breaking day is basically the same. The damage ratio of garlic buds is the highest at the speed of 3 m/s, and the damage of other speeds is relatively small. Figure 7(c) is the relative damage ratio heat map, 10 mm chain and 3 m/s speed under the condition of heat map color from blue to red at the fastest speed, indicating that the heavier the chain, the faster the speed, the easier the garlic buds damage. Figure 7(d) is the perfectness ratio heat map, the color of the heat map corresponding to 8 mm chain and 2.5 m/s speed condition is redder than other conditions on the same breaking days, indicating that the garlic bud perfectness ratio is the highest at this time.

3.2 Analysis of optimum film breaking conditions

When the experiment was carried out to the fourth day, garlic buds had basically broken out, and the final data were obtained. Because of the main factors affecting the effect and efficiency of membrane breaking are the type of chain mechanism, weight, and working speed, the data are analyzed by Prism software, as shown in figure 8.



(a) (b) (c) (d)

Fig. 8. Comparative analysis of different data processing methods on the fourth day of machine film breaking. (a, b, c, d) respectively represent the broken line changes of Q1, Q2, Q3, and Q4 at the same speed with different chains as abscissa.

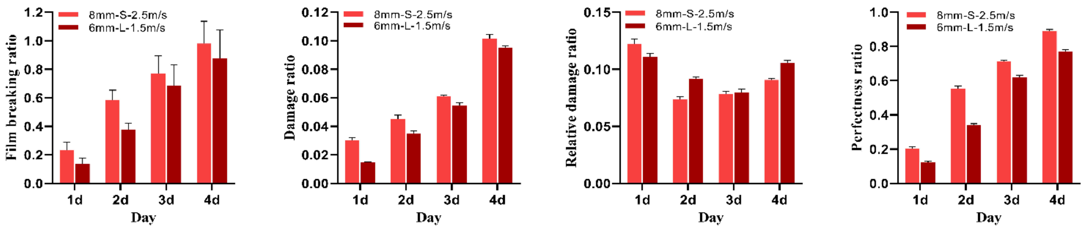
Figure 8(a) shows that the same chain speed in 2.5 m/s and 3 m/s garlic buds film breaking ratio is the highest, the lowest at 1 m/s, and with the increase of chain weight film breaking ratio also gradually increased. In addition, it can also show that at the same speed, garlic buds broken film ratio under 8mm-L, 8mm-S, 10mm-L, and 10mm-S chains is relatively high, and increases gradually with the increase of speed, but the growth rate is slow. Figure 8(b) and 8(c) shows that the same chain at the speed of 3 m/s, garlic bud damage ratio and relative damage ratio are the highest. Moreover, the damage ratio and relative damage ratio of garlic buds using 10mm-S and 10mm-L chains are higher than other chains, reaching about 20 %, and other chains are 10 %. Figure 8 (d) shows that at the same speed, the garlic bud integrity rate using 8mm-s chain is the highest, more than 85%, and the garlic bud integrity rate using 5mm-s chain is the lowest. When the speed was 2.5 m/s, the garlic bud integrity rate was the highest, and it was relatively low at 1 m/s. From the above analysis, it can be seen that compared with other film breaking conditions, the garlic bud breaking ratio of 8mm-S chain at 2.5 m/s forward speed is higher, the garlic bud damage ratio is relatively low, and the perfectness ratio is the highest. Therefore, the best chain for film breaking is 8mm-S, and the best operating speed is 2.5 m/s.

3.3 Comparison of mechanical and manual film breaking

The comparison test of artificial and machine film breaking was carried out to analyze the film breaking effect and efficiency. 6 mm stainless steel long ring chain and 1.5 m/s forward speed are mostly used for manual film breaking. The above analysis shows that the optimal film breaking parameters of the machine are 8 mm stainless steel short ring chain and 2.5 m/s forward speed. The actual operation comparison of man-machine breaking film in the field is shown in figure 9. The data comparison between machine film breaking and manual film breaking is shown in figure 10. Among them, 8mm-S-2.5m/s represents the conditions corresponding to machine film breaking, and 6mm-L-1.5m/s represents the conditions corresponding to manual film breaking.

Fig. 9. The actual operation diagram of machine field film breaking.

Figure 10(a) shows that under the condition of 8mm-S-2.5m/s, garlic bud film breaking ratio is always greater than 6mm-L-1.5m/s, and the final garlic bud film breaking ratio is 10.5 % higher than manual. Figure 10(b) shows that the garlic bud damage ratio under the condition of 6mm-L-1.5m/s is always lower than that under the condition of 8mm-s-2.5m/s, but with the increase of broken film days, the damage ratio gap between the two is getting smaller and smaller. It can be seen from Figure 10(c) that except the first day, the relative damage ratio of garlic buds under the condition of 8 mm−L−2.5m/s was relatively low, indicating that the growth rate of the number of broken film of garlic buds under the condition of 8 mm−L−2.5m/s was greater than that of the damage number of garlic buds. From the figure 10(d), in the whole process of film breaking, the garlic bud perfectness ratio under the condition of 8mm-s-2.5m/s is always higher than that under the condition of 6mm-L-1.5m/s, and the garlic bud perfectness ratio of machine breaking film is 12.23 % higher than that of manual breaking film. Therefore, the overall effect of machine breaking is better than that of manual breaking, which proves that the machine breaking conditions under the combination of 8 mm−S chain and 2.5 m/s forward speed are reliable and reasonable. Considering the film breaking amplitude and speed, the film breaking efficiency of the machine is 5.4 hm^2/h, and the manual film breaking efficiency is 2.16 hm^2/h. The film-breaking efficiency of the machine is about 2.5 times that of the manual.



(a) (b) (c) (d)

Fig. 10. Comparison of data corresponding to the machine film-broken condition and the manual film-broken condition

4. Conclusions

In view of the fact that there is no relevant machine available in garlic planting broken film link, a chain dragging garlic film breaker supported by visual aid and remote control was designed. Crawler walking device solves the problem of sinking and slipping when operating in the field, the folding frame can meet the needs of one to three border film-breaking operations, the combination of visual-aid device and remote-control device makes the machine operation more convenient and greatly reduces the labor intensity.

Through the overall analysis of film breaking data, the selection of key equipment and the optimization of working parameters, the optimal film breaking chain is determined to be 8 mm stainless steel short ring and the optimal operating speed is 2.5 m/s. The corresponding film breaking ratio of garlic buds was 98 %, the damage ratio of garlic buds was 9 %, the relative damage ratio of garlic buds was 9.1 %, and the perfectness ratio of garlic buds was 89 %. The results showed that the film breaking ratio of the machine is 10.5% higher than that of manual, the damage of garlic bud is basically the same, while the overall film breaking effect was better than that of manual film breaking. the maximum operating efficiency of the machine was 5.4 hm^2/h, about 2.5 times higher than that of manual, which improved the field film breaking efficiency.

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