

## 葡萄修剪机的研制与试验

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**摘要:**【目的】解决我国葡萄园夏季修剪劳动强度大、作业效率低等问题。【方法】应用机械设计理论与方法,并结合我国葡萄标准栽培模式的特点及修剪的技术要求,研制了一种与履带拖拉机配套的、适于葡萄园夏季修剪作业的葡萄修剪机。该设备主要由液压系统和修剪系统两部分组成。动力由拖拉机的后动力输出轴经万向传动轴带动液压系统工作,经双联油泵将液压油一路供给两个调节油缸和回转马达,以实现伸缩臂的升降、折叠和修剪角度的调节,另一路直接供给切割马达驱动切割刀工作,从而完成棚架、V架和篱架三种栽培架式的葡萄修剪工作。【结果】样机田间试验结果表明,该修剪机工作稳定,适应性强,切割效果良好,作业效率高。按试验时的作业速度计算,该机每h修剪3 000 m,而人工每小时修剪约100 m,剪梢效率是人工修剪的30倍。【结论】葡萄修剪机是根据我国葡萄标准栽培模式和修剪的技术要求、满足产业需求而研发的,该机的研制成功为葡萄简化修剪栽培技术的研发和推广奠定了装备基础,具有较好的推广前景。

**关键词:**葡萄;修剪机;研制

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## Manufacutre and field testing of the pruning machine for grapevines

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**Abstract:**【Objective】Grapevine pruning is an important part of vineyard management. It not only controls effectively the space configuration of the main arms and side canes, enhances the overall ventilation and transmittance of the orchard and helps the fruit growth and bearing, but also improves the fruit yield and quality, and affects directly the economic benefit. Research on pruning machinery started early in Europe, America and a few additional countries, and the machine models were also complete. The pruning machines have been combined with automation technology and artificial intelligence, and the working speed is faster and the efficiency is higher. Some models also have cane recovery equipment and combine with picking machinery. However, the development of pruning machinery started late in China and actually few models have been developed so far. At present, most of the pruning machines are mainly hand-held, supplemented with electric and pneumatic pruning. At present, there are many problems in practical grapevine pruning, like large labor intensity and low working efficiency. To solve the problems, a new pruning machine is required to develop for improving the overall level of orchard mech-

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anization in Chinese grape production.【Methods】By application of mechanical design theory and methods, the grapevine pruning machine was developed, fully considering the characteristics of the standard cultivation models of Chinese vineyards and the technical requirements. The pruning machine took the crawler tractors as power, which was mainly composed of the hydraulic system and the pruning system. The hydraulic system was fixed to the rear of the crawler tractors by the suspension mechanism, and it was mainly composed of hydraulic oil tank, hydraulic pumps, electromagnetic reversing valves, hydraulic cylinders, hydraulic motors and so on. In order to ensure the pruning speed and work quality, the double pump was adopted and a hydraulic pump controlled separately the cutting motor to complete the pruning work. Gear pumps and gear motors were also selected. The pruning system was attached to the front of the crawler tractor and it was made up of cutter, cutter shaft, pulley, belts, protective cover and so on. The power was driven to the hydraulic system by the rear power output shaft of the crawler tractor and the universal drive shaft. The hydraulic oil was pressurized and divided to two ways by the double oil pumps. One way was that the hydraulic oil flowed to two regulating oil cylinders and the rotary motor to realize the adjustment of the lifting and folding and pruning angles of the arm. Another way was that the hydraulic oil was supplied directly to the cutting motor to drive the cutter. The grapevine pruning worked well for the three cultivation models of trellis, V-system and hedge. In the pruning system, the characteristics of the three kinds of cutters were compared, and the cutter type of the pruning machine was determined to be the rotary cutter. The rotation speed of the cutter was determined to be  $2\ 700\text{ r}\cdot\text{min}^{-1}$  and the size and number of the cutter were also determined. In the hydraulic system, the hydraulic system diagram was designed and the type of hydraulic motor and pump were determined. The field testings were conducted on September 11, 2016 and July 20, 2017 at the Grape Core Technology Experimental Demonstration Park of the Research Institute of Pomology, Chinese Academy of Agricultural Sciences. The testing conditions are as follows: the cultivation models of the grape include trellis, V-system and hedge, and the spacing of the V-system and trellis is  $0.7\text{ m}\times3.5\text{ m}$ , and the spacing of hedge is  $0.7\text{ m}\times4.0\text{ m}$ , and the working speed of the pruning machine is  $1\text{ m}\cdot\text{s}^{-1}$ .【Results】The field test showed that the grapevine pruning machine was stable, adaptable and efficient, and the work efficiency of the machine was 30 times higher than that of the hand-pruning, and the pruning effect was also desirable.【Conclusion】The grapevine pruning machine was developed according to the standard cultivation models and pruning requirement of the grapevines in China to meet the demand of the industry. The development of the machine has laid the equipment foundation for the research on the simplified pruning and cultivation techniques of grapes, and showed a good prospect for popularization. Because the whole plant pruning method has to be adopted by the machine, it would cause damage to the leaves. Take care of spraying the fungicides in time and prevent from the disease after pruning. It might be suggested that the pruning machine needs to be upgraded in the aspects of automation and intelligence to improve the work efficiency in the further.

**Key words:** Grape; Pruning machine; Design

葡萄是一种藤本蔓生的浆果，在我国果树产业的地位非常重要<sup>[1]</sup>。截至2016年底，我国葡萄的栽培面积为80.96万hm<sup>2</sup>，产量为1 374.5万t，继苹果、柑橘、梨、桃之后，已成为我国第5大水果。整形修剪是葡萄园管理的一项重要环节，不仅有效控制主副梢的空间配置、增强果园整体通风透光性、有助于果树生长与结果，而且能够提高果品产量和品质、直接影响其经济效益<sup>[2-5]</sup>。整形修剪按时间分为夏季修

剪和冬季修剪，夏季修剪就是通过对结果枝和营养枝及副梢的疏除或摘心，达到促进葡萄花芽分化、开花坐果和提高果实品质的目的<sup>[6]</sup>；按修剪方式分为单枝修剪和整株几何修剪<sup>[7]</sup>，单枝修剪具有准确合理、劳动强度大、作业效率低的特点，而整株几何修剪作业效率高、但会出现损伤枝条的情况。

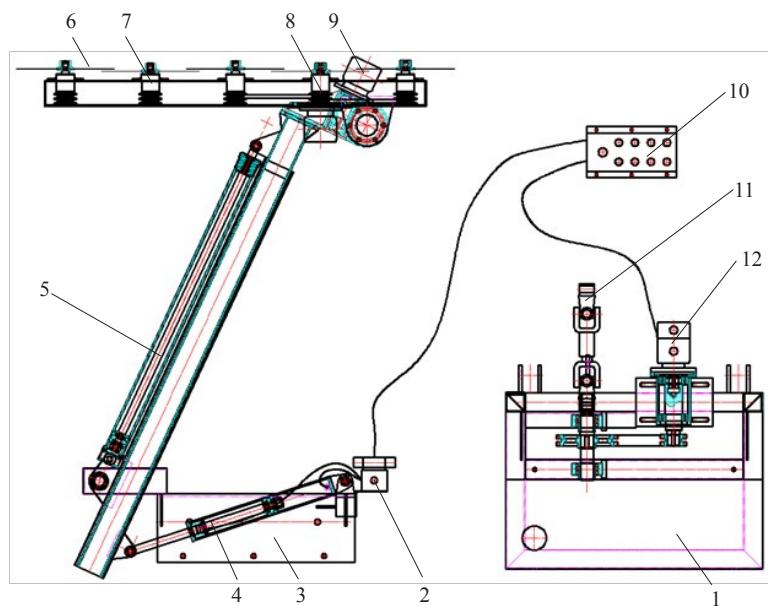
欧美等国家对修剪机械的研究起步较早，机型也较齐全，已采用自动化技术和人工智能相结合，作

业速度更快、效率更高,有的机型还设有枝条回收装置、与采摘机械相结合等<sup>[8-9]</sup>。国内修剪机械的研制起步较晚,机型少,目前大部分以手持式修剪机械为主,辅以电动或气动修剪。而实现葡萄的机械化修剪是推进我国葡萄产业发展的必由之路。为此,结合我国葡萄标准栽培模式的特点及修剪的技术要

求,开展了葡萄修剪机的研制,并进行了样机的田间试验。

## 1 葡萄修剪机结构与主要技术参数

整机结构如图1所示,主要由机架、液压泵站、电磁阀、液压马达、切割刀、调节油缸等组成,液压泵



1. 液压油箱; 2. 电磁换向阀; 3. 机架; 4. 摆动油缸; 5. 升降油缸; 6. 刀片; 7. 刀轴; 8. 切割马达; 9. 回转马达; 10. 控制器; 11. 输入轴; 12. 双联油泵。

1. Hydraulic oil tank; 2. Electromagnetic reversing valve; 3. Frame; 4. Swing cylinder; 5. Lift cylinder; 6. Blades; 7. Shafts; 8. Cutting motor; 9. Rotary motor; 10. Controller; 11. Input shaft; 12. Double pumps.

图1 葡萄新梢修剪机总体结构  
Fig. 1 Overall structure of the pruning machine for grapes

站三点悬挂在拖拉机后方,切割刀、刀轴等组成的修剪系统挂接于拖拉机前方。动力由拖拉机的后动力输出轴经万向传动轴带动液压系统工作,经双联油泵加压将液压油一路供给两个调节油缸和回转马达,以实现伸缩臂的升降、折叠和修剪角度的调节;另一路直接供给切割马达驱动切割刀工作,从而完成平棚架、V型架和直立篱架3种栽培架式的葡萄修剪工作。主要技术参数见表1。

表1 整机主要技术参数

Table 1 Main work parameters of the machine

| 名称 Name  | 参数 Parameters     |
|--|-------------------|
| 外形尺寸(长×宽×高)<br>Dimensions(length×width×height)/mm×mm×mm  | 1 350×1 900×2 450 |
| 配套动力 Matching power/kW                                   | 22~40.4           |
| 整机质量 Machine quality/kg                                  | 280               |
| 作业速度 Work speed/(km·h <sup>-1</sup> )                    | 2~4               |
| 刀轴转速 Rotating speed of the shafts/(r·min <sup>-1</sup> ) | 2 700             |

## 2 关键部件的设计

### 2.1 切割器的设计

2.1.1 切割器的选型 切割器类型主要有往复式、圆盘锯式和转刀式3类<sup>[10]</sup>,往复式切割器是利用动刀片相对于定刀或动刀作往复的剪切运动进行切割,在收获机械上得到广泛应用,特点是工作可靠、修剪质量好,但对不同栽培模式的葡萄修剪适应性差<sup>[11]</sup>,且往复运动产生的惯性力和冲击载荷较大,对切割器本身各部件的寿命有一定的影响<sup>[12]</sup>;圆盘锯式切割器切割能力强,适于中、高速联合作业,但功率消耗大、割茬不整齐;转刀式切割器运转平稳,与往复式割刀和圆盘式割刀相比,其工作效率更高,更适用于修剪如葡萄副梢这样比较细嫩的枝条。比较以上三种切割器的特点,确定葡萄修剪机的切割器类型为转刀式切割器。

2.1.2 切割器转速的确定 转刀式切割器工作时,刀片的运动由旋转运动和前进方向的直线运动所合成,刀片的某一点对投影面所扫过的面积为余摆线。根据研究资料,无支撑切割时,刀刃根部的最低极限线速度为  $30 \text{ m} \cdot \text{s}^{-1}$ <sup>[12]</sup>。考虑本机的作业对象是尚未木质化的葡萄新梢,剪切强度较低、切割阻力较小,因此确定切割速度  $V_g$  取  $30 \text{ m} \cdot \text{s}^{-1}$ ,机器设计最大前进速度  $V_j$  为  $4 \text{ km} \cdot \text{h}^{-1}$ ,取  $1.1 \text{ m} \cdot \text{s}^{-1}$ ,刀刃根部到旋转中心距离  $r$ (见图2中 OA)约为  $110 \text{ mm}$ ( $0.11 \text{ m}$ ),则切割器的转速  $n$  为:

$$n = 30(V_g + V_j)/\pi r$$

计算得转速  $n=2701 \text{ r} \cdot \text{min}^{-1}$ ,最终确定为  $n=2700 \text{ r} \cdot \text{min}^{-1}$ 。

2.1.3 刀片尺寸和刀片数的确定 根据现有葡萄的栽培架式,篱架栽培副梢修剪的高度一般为  $1300 \text{ mm}$ ,并考虑实际作业情况确定本机的工作幅宽为  $1350 \text{ mm}$ 。在葡萄新梢修剪机工作幅宽确定的情况下,刀片尺寸越大,需要数量就越少,传动系统就越简单,但是尺寸大导致质量也大,所需惯性力也

大,对传动系统的可靠性要求也高。综上确定刀片的具体尺寸如图2所示。为防止漏剪,相邻两刀片之间的轨迹要有一定的重叠,重叠量一般为  $30\sim60 \text{ mm}$ ,本机取  $40 \text{ mm}$ ,确定刀片数量为 5。刀轴之间采用带传动,带传动具有结构简单、调整方便、不需润滑等特点,单根 A型V带即可满足使用要求。

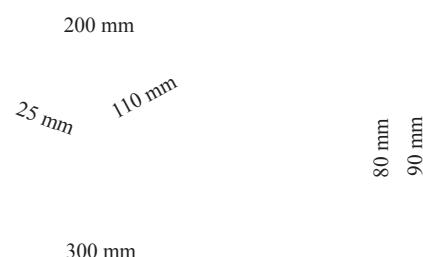
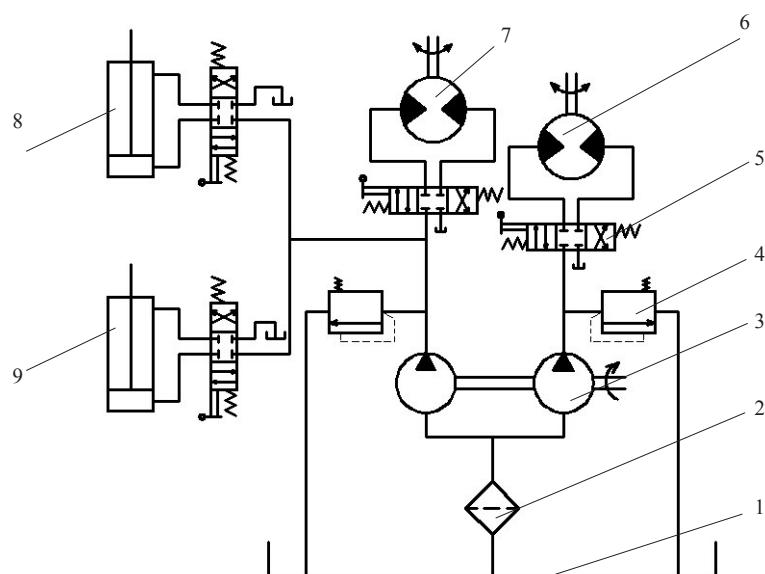


图2 刀片结构及尺寸

Fig. 2 The structure and size of blade

## 2.2 液压系统的设计

液压系统主要由液压油箱、液压泵、油管、电磁换向阀、液压缸、液压马达等组成,葡萄修剪机的液压系统图如图3所示。



1. 液压油箱;2. 过滤器;3. 双联油泵;4. 溢流阀;5. 电磁换向阀;6. 切割马达;7. 回转马达;8. 升降油缸;9. 摆动油缸。

1. Hydraulic tank; 2. Filter; 3. Double pumps; 4. Relief valve; 5. Electromagnetic reversing valve; 6. Cutting motor; 7. Rotary motor; 8. Lift cylinder; 9. Swing cylinder.

图3 液压系统  
Fig. 3 Hydraulic system diagram

2.2.1 液压马达的选用 液压马达种类较多,有齿轮马达、叶片马达、摆线马达、轴向柱塞马达、径向柱塞马达和内曲线径向马达等<sup>[13]</sup>,其中齿轮马达结构简单、重量轻、价格低廉、适用于高转速低转矩

情况,因此,选用齿轮马达作为动力元件,CMF-DA-E320 齿轮马达的进、出油口通径为  $\Phi 15 \text{ mm}$ ,在压力为  $16 \text{ MPa}$  时,输入功率为  $16.1 \text{ kW}$ ,转速为  $2000\sim3000 \text{ r} \cdot \text{min}^{-1}$ ,符合使用要求。

2.2.2 液压系统的流量 液压马达的排量  $V=20 \text{ mL} \cdot \text{r}^{-1}$ ,按照最大转速  $n=3\,000 \text{ r} \cdot \text{min}^{-1}$ 计算,最大流量  $q_{\max}=60 \text{ L} \cdot \text{min}^{-1}$ ,实际工作过程中,液压系统会有15%左右压力损失,因此液压系统实际流量  $q_{\text{实}}=69 \text{ L} \cdot \text{min}^{-1}$ 。

2.2.3 液压泵的选用 本机为保证修剪转速及作业效果,采用双联泵,由一个液压泵单独控制切割马达完成修剪作业。齿轮泵在定量液压系统中有着广泛应用,因此,选用齿轮泵作为葡萄修剪机的动力源。CBG2050L齿轮泵工作可靠,寿命长,经济实用,由于CBG2050L齿轮泵的排量  $V_{\text{泵}}=50 \text{ mL} \cdot \text{r}^{-1}$ ,动力输出轴的转速  $n_{\text{输出}}=540 \text{ r} \cdot \text{min}^{-1}$ ,而液压系统实际流量  $q_{\text{实}}=69 \text{ L} \cdot \text{min}^{-1}$ ,直接连接需要给油泵增速。根据液压系统的实际流量并考虑压力损失(15%),确定液压油泵的理论流量  $q_{\text{理论}}=q_{\text{实}} \times (1+15\%)=79 \text{ L} \cdot \text{min}^{-1}$ ,相应齿轮泵的转速  $n_{\text{泵}}=q_{\text{理论}}/V_{\text{泵}} \times 1\,000=1\,580 \text{ r} \cdot \text{min}^{-1}$ ,传动比  $i=n_{\text{输出}}/n_{\text{泵}}=0.34$ ,采用40/14双排套筒滚子链增

速即可满足使用要求。

2.2.4 液压油箱容积的确定 由于本机工作为间歇工作,因此,液压油箱的容积可以适当减小,因为液压系统理论流量  $q_{\text{理论}}=79 \text{ L} \cdot \text{min}^{-1}$ ,在生产过程中实际使用的发动机转速约为额定转速的80%左右,因此,根据液压手册有关设计要求,确定液压油箱总容积为120 L,防止液压油在工作时因摇晃而溢出油箱。

### 3 田间试验

#### 3.1 试验条件

样机的田间试验于2016年9月和2017年7月在中国农业科学院果树研究所葡萄核心技术试验示范园进行。试验条件如下:葡萄试验示范园栽培架式为棚架、V架和篱架栽培模式三种,其中V架和篱架的株行距为0.7 m×3.5 m,棚架的株行距为0.7 m×4.0 m,机器作业速度为1 m·s<sup>-1</sup>,样机及田间试验如图4所示。



图4 样机及田间试验  
Fig. 4 The prototype and field experiment

### 3.2 试验结果与分析

样机田间试验结果表明:研发的葡萄修剪机工作稳定、适应性强、切割效果良好、仿形效果良好、效率高。按试验时的作业速度,该机每h修剪3 000 m,而人工每小时修剪约100 m,剪梢效率是人工的30倍。由于该机采用整株修剪方式,会造成叶片损伤,建议采用该机修剪后及时喷施杀菌剂防止叶片感染病害。

### 4 讨论

该葡萄修剪机是根据我国葡萄标准栽培模式和

修剪的技术要求,满足产业需求而研发的。该机的研制成功为葡萄简化修剪栽培技术的研发和推广奠定了装备基础,具有较好的推广前景。该机切割器的类型最终确定为转刀式切割器,这与陈魁等<sup>[1]</sup>、王哲等<sup>[14]</sup>所设计的葡萄修剪机具切割器类型有所不同,原因归结于切割器的特点以及作业对象的种类,相同的是为进一步提高葡萄修剪机的作业效果,现有机械都需在自动化和智能化方面进行升级改造。此外,开展不同果树枝条力学特性的研究,通过建立枝条含水率、直径等与剪切参数的数学模型探究高效、省力、适应性强的修剪途径。

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