

蒜种盒机械投放过程运动学分析与参数优化试验

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摘要: 针对种盒式大蒜播种方案, 为检验倾斜输送带式蒜种盒投放方式的可行性, 设计了预植蒜种的可降解蒜种盒和输送带式种盒投放试验台。对蒜种盒投放过程进行了运动学分析, 建立了蒜种盒运动速度、输送带倾角与投放后相邻蒜种盒间隙等相关参数间的数学模型, 明确了蒜种盒投放间隙的影响因素及变化规律。通过蒜种盒投放过程的受力分析, 确定了蒜种盒触地后不与地面产生滑动的条件和方法。为了验证理论分析结果和大蒜播种方案的可行性, 进行了输送带倾角、行驶速度等单因素试验和正交试验, 结果显示, 输送带倾角为 30°、试验台运动速度为 0.75 km/h, 投放效果较好。输送带倾角对前后蒜种盒投放后的间隙影响显著, 通过优化蒜种盒长度两端尺寸, 可有效消除投放后蒜种盒衔接间隙, 保持播种株距稳定。

关键词: 农业机械; 运动学; 输送带; 大蒜; 蒜种盒; 播种试验台

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0 引言

大蒜是中国主要经济作物之一^[1-5], 2014 年大蒜种植面积达 75 万 hm^2 , 占全球 60% 以上。由于大蒜播种“根下尖上、直立栽种”的特殊农艺要求, 长期以来只能依靠人工播种, 一人一天仅能种植 220 m^2 。国内外一些高校和科研院所对大蒜播种机械进行了研究^[6-12]。国外大蒜栽植机械常见的有链勺式、盘勺式、振动式以及种带式。前 3 种基本实现了大蒜单粒精播, 但芽尖向上的姿态得不到有效控制; 种带式播种方式下种带入沟后的直立状态难以控制; 法国、捷克斯洛伐克研制的大蒜栽植机采用蒜瓣扶正机构、振动斗槽定向器, 基本上解决了蒜瓣输送过程的定向问题但不能控制入沟后的姿态。中国农业机械化科学研究院、辽宁省农业机械研究所研制的全自动大蒜栽植机能够保证蒜瓣下落时的直立状态, 但其入沟后的直立率不高; 山东省农业机械研究所采用锥形螺旋导管试验蒜瓣下落姿态有较好的定向作用, 但落入土穴后蒜瓣芽尖的

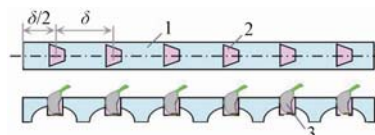
朝向仍是随机的。

针对这种现状, 提出了种盒式大蒜机械播种方式, 即采用蒜种盒预植蒜种, 再实施种盒田间投放, 以确保大蒜“根下尖上、直立栽种”。为此, 进行了种盒投放过程分析与试验。

1 蒜种盒与种盒投放试验台

1.1 蒜种盒设计

针对现有大蒜播种机械存在的 2 个主要问题, 一是蒜种不能完全调头^[13-17]; 二是蒜种在种沟内不能保持直立, 设计了可降解蒜种盒(长×宽×高: 600 mm×25 mm×30 mm), 如图 1 所示。蒜种盒材料采用废纸浆、植物秸秆等无污染可降解材料制成, 种盒上有多个种穴, 种穴底部有孔, 相邻种穴间隔为大蒜株距。事先由人工将蒜种“植”于种穴, 然后由专用种盒播种机实施田间播种。



1. 蒜种盒 2. 种穴 3. 蒜种
1. Garlic box 2. Seed hill 3. Seed clove

注: δ 为种穴间距。

Note: δ expresses distance of seed clove.

图 1 蒜种盒

Fig.1 Garlic box

1.2 蒜种盒投放试验台结构与工作原理

为了验证播种方案的可行性, 设计了蒜种盒投放试验

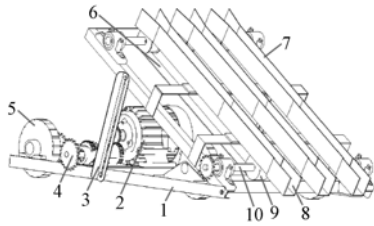
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台,如图2所示。主要由机架、输送带及倾角调节装置、蒜种盒扶持板、导向板、调速电机、传动系统、地轮等组成。地轮由电机提供动力,电机转速由工控机控制。



1.机架 2.电机 3.输送带倾角调节装置 4.传动系统 5.地轮 6.输送带
7.蒜种盒扶持板 8.导向板 9.带轮 10.带轮轴
1. Frame 2. Motor 3. Adjusting device of belt tilt angle 4. Transmission system 5. Ground wheel 6. Conveyor belt 7. Baffle plate 8. Guide plate 9. Pulley 10. Axle of pulley

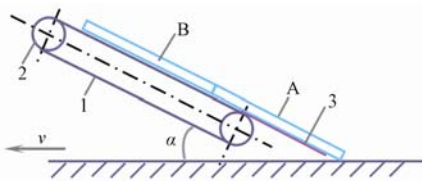
图2 蒜种盒投放试验台

Fig.2 Structure diagram of test-bed

将蒜种盒首尾相接放到输送带上,地轮通过传动系统带动输送带向下输送,同时驱动试验台前移。蒜种盒扶持板安装在输送带两侧,防止蒜种盒在输送过程中侧方滑落;导向板安装在输送带下面,引导蒜种盒平稳落地,导向板两侧有竖直挡板,防止种盒投放过程侧翻。输送带相对地面的倾角可调。

1.3 传动比的确定

蒜种盒投放过程如图3所示。蒜种盒投放后,要求按顺序首尾相接排列,因此试验台运动速度跟输送带速度相匹配。



1.带轮 2.输送带 3.导向板
1. Pulley 2. Conveyor belt 3. Guide plate

注: v 为试验台运动速度, $\text{km}\cdot\text{h}^{-1}$; α 为输送带与地面夹角, rad 。A、B 为蒜种盒。
Note: v expresses running speed of test bed, $\text{km}\cdot\text{h}^{-1}$; α expresses angle between belt and ground, rad . A, B were garlic boxes.

图3 蒜种盒投放过程

Fig.3 Schematic diagram of garlic box locus

令蒜种盒 A 前端触地到蒜种盒 A 完全落地的时间为 t , 则时间 t 内试验台前近距离应等于种盒长度,

$$v \cdot t = L, \quad (1)$$

式中 L 为蒜种盒长度, mm 。

为了保持蒜种盒 B 与蒜种盒 A 首尾相连,若不考虑蒜种盒与输送带的相对滑动,则时间 t 内,蒜种盒 B 的移动距离也应等于种盒长度,

$$v_1 \cdot t = L, \quad (2)$$

式中 v_1 为输送带运动速度, km/h 。

由公式 (1)、(2) 可知

$$v = v_1. \quad (3)$$

根据公式 (3), 由地轮和带轮直径可计算出两者之间的传动比。

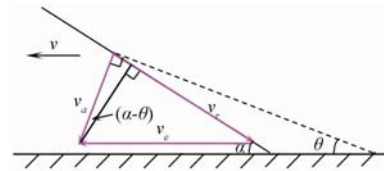
2 蒜种盒投放过程分析

试验测得,蒜种盒与输送带的摩擦角为 37.4° , 为避免蒜种盒的滑动,确定输送带倾角 $\leq 35^\circ$ 。

在放置蒜种盒时,应保持首尾相接,最下面的蒜种盒前端触地,如图3中蒜种盒 A 所示,以防止漏播。

2.1 蒜种盒投放速度

蒜种盒 A 前端触地时,蒜种盒 A 的运动为绕触地点的旋转运动,蒜种盒 A 末端的运动速度分解如图4所示^[18-20]。



注: v_a 为蒜种盒 A 末端的绝对速度, $\text{km}\cdot\text{h}^{-1}$; 大小、方向随着蒜种盒的运动而变化; v_e 为蒜种盒 A 末端牵连速度, $\text{km}\cdot\text{h}^{-1}$; v_r 为蒜种盒 A 末端相对速度, $\text{km}\cdot\text{h}^{-1}$; 方向沿输送带向下,大小随蒜种盒的运动而变化; 为蒜种盒与地面夹角, rad , $0 \leq \theta \leq \alpha$ 。

Note: v_a expresses absolute velocity of the end of garlic box A, $\text{km}\cdot\text{h}^{-1}$, its value and direction change momentarily; v_e expresses following velocity of the end of garlic box A, $\text{km}\cdot\text{h}^{-1}$; v_r expresses relative velocity of the end of garlic box A, $\text{km}\cdot\text{h}^{-1}$, its value change momentarily and its direction is downward along belt; θ expresses angle between garlic box and ground, rad , $0 \leq \theta \leq \alpha$.

图4 蒜种盒速度合成

Fig.4 Composition of velocity of garlic box

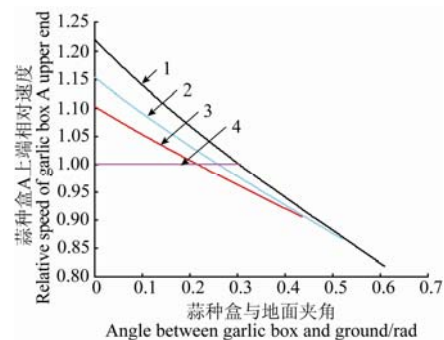
盒的摩擦力和上面蒜种盒对该蒜种盒的挤压力,由题意知:

$$\vec{V}_a = \vec{V}_e + \vec{V}_r, \quad (4)$$

$$v_e = v$$

$$v_r = v \cdot \cos \alpha + v \cdot \sin \alpha \cdot \tan(\alpha - \theta). \quad (5)$$

蒜种盒 A 末端相对速度 v_r 与 θ 的关系如图5所示。



注: 曲线 1、2、3 分别表示输送带倾角为 35° 、 30° 、 25° 时蒜种盒 A 前端触地后其末端的相对速度; 直线 4 表示试验台运动速度 v (设为 1)。

Note: Curves 1, 2, 3 express respectively relative velocity of the end of garlic box A when the front of garlic box A touches ground as the belt angle is 35° , 30° , 25° ; Linear 4 expresses running speed of test bed (suppose it is 1).

图5 蒜种盒 A 末端相对速度与其相对地面夹角的关系

Fig.5 Relationship between v_r and θ for garlic box A

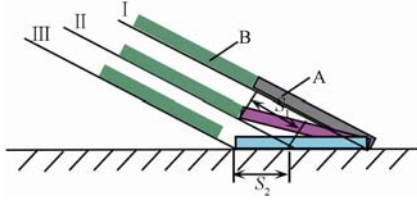
2.2 蒜种盒投放间隙

由图5可知,蒜种盒 A 的相对速度随着蒜种盒与地面夹角的减小而增大,根据蒜种盒相对速度的变化,可将蒜种盒的运动分为 2 个阶段。

第 1 阶段,蒜种盒 A 前端触地开始到 $v_r = v$, 该阶段内蒜种盒 A 末端沿输送带方向的速度 $v_r < v$, 蒜种盒 A 末

端与蒜种盒 B 均以速度 v_r 沿输送带向下运动;

第 2 阶段, 从 $v_r=v$ 到蒜种盒 A 完全落地, 该阶段内 $v_r>v$, 蒜种盒 A 末端以速度 v_r 沿输送带向下运动, 而蒜种盒 B 的速度仍为 v , 此时 2 个蒜种盒之间会产生间隙, 如图 6 所示。



注: I、II、III 分别表示蒜种盒 A 前端触地、蒜种盒 A 末端相对运动速度 $v_r=v$ 、蒜种盒 A 全部落地 3 个瞬间; S_1 表示由 II 到 III 蒜种盒 A 末端沿输送带下滑的距离, mm; S_2 表示由 II 到 III 机器前进的距离, mm。

Note: I, II, III express respectively three moment of the front of garlic box A touching ground, relative velocity of the end of garlic box A $v_r=v$, garlic box A all landing; S_1 expresses the distance of the end of garlic box A running along belt from II to III, mm; S_2 expresses the distance of test bed running from II to III, mm.

图 6 蒜种盒投放过程
Fig.6 Process of garlic box putting

由于输送带运动速度等于机器前进速度, 所以由 II 到 III 蒜种盒 B 随输送带的位移等于 S_2 。

当 $v_r=v$ 时,

$$\cos \alpha + \sin \alpha \tan (\alpha - \theta_0) = 1. \quad (7)$$

θ_0 与 α 的关系如图 7 所示。

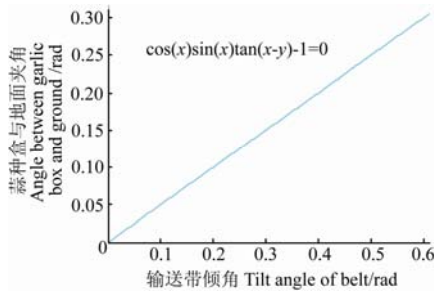


图 7 $v_r=v$ 时 θ_0 与 α 的关系
Fig.7 Relationship between θ_0 and α as $v_r = v$

由图 7 知 $\theta_0 \approx \alpha/2$ 。

由图 6 知,

$$S_1 = \frac{L \cdot \sin \theta_0}{\sin \alpha}, \quad (8)$$

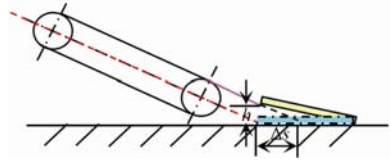
$$S_2 = L - \left(L \cdot \cos \theta_0 - \frac{L \cdot \sin \theta_0}{\tan \alpha} \right). \quad (9)$$

则相邻蒜种盒铺放到地面后产生的间隙

$$\begin{aligned} \Delta S &= S_1 - S_2 = \\ &= \frac{L \cdot \sin \theta_0}{\sin \alpha} - L + \left(L \cdot \cos \theta_0 - \frac{L \cdot \sin \theta_0}{\tan \alpha} \right) = \\ &= \frac{L \cdot \sin \theta_0}{\sin \alpha} + L \cdot \cos \theta_0 - \frac{L \cdot \sin \theta_0}{\tan \alpha} - L = \\ &= L \cdot \left(\frac{\sin \theta_0}{\sin \alpha} + \cos \theta_0 - \frac{\sin \theta_0}{\tan \alpha} - 1 \right) \end{aligned} \quad (10)$$

另外, 为防止导向板碰触地面, 导向板前端需离开

地面一定高度 h , 这将导致蒜种盒 A 提前落地, 使种盒 A、B 间隙增加 Δs , 如图 8 所示。



注: Δs 为增加的间隙。

Note: Δs is the added interval when falling to ground ahead time.

图 8 蒜种盒铺放

Fig.8 Garlic box laying down

$$\Delta s = h / \sin \alpha. \quad (11)$$

此时相邻蒜种盒之间的间隙为

$$\Delta S + \Delta s = L \cdot \left(\frac{\sin \theta_0}{\sin \alpha} + \cos \theta_0 - \frac{\sin \theta_0}{\tan \alpha} - 1 \right) + \frac{h}{\sin \alpha}. \quad (12)$$

由公式 (12) 可知, 蒜种盒投放后的间隙与试验台运动速度无关。

取 $L=600$ mm, 投放后蒜种盒间隙与输送带倾角的关系如图 9 所示。

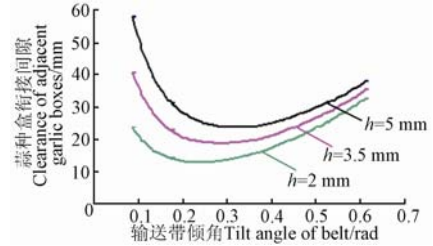


图 9 蒜种盒间隙与输送带倾角的关系

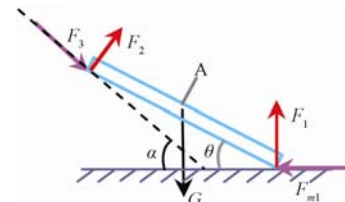
Fig.9 Relationship between clearance of garlic box and oblique angle of conveyor

由图 9 可以看出, 蒜种盒落地后, 相邻蒜种盒的间隙随输送带倾角的增大呈先减小后增大的趋势; 输送带倾角一定, 蒜种盒间隙与导向板前端离地高度 h 成正相关关系。

2.3 蒜种盒与地面不产生滑动的条件

上述分析是在蒜种盒 A 与地面不发生滑动的前提下, 下面分析蒜种盒不产生滑动的条件。

试验测得, 蒜种盒与土壤、蒜种盒与输送带的摩擦系数分别为 $\mu_1=1.935$ 、 $\mu_2=0.765$ 。如前所述, 蒜种盒投放过程可分为 2 个阶段: 第 1 阶段, 即蒜种盒与地面夹角从 α 到 $\alpha/2$, 此时触地蒜种盒受力如图 10 所示。



注: F_1 为地面对蒜种盒的支撑力, N; F_2 为输送带对蒜种盒的支撑力, N; F_3 为输送带对蒜种盒的摩擦力和上面蒜种盒对下面蒜种盒的挤压力, N; F_{m1} 为地面对蒜种盒的摩擦力, N; G 为蒜种盒重量, N。

Note: F_1 expresses the supporting force that ground effects on garlic, N; F_2 expresses the supporting force that belt effects on garlic, N; F_3 expresses the sum of friction force that belt effects on garlic and extrusion force that above garlic box effects on lower garlic box, N; F_{m1} expresses the friction force that ground effects on garlic, N; G expresses the garlic box weight, N.

图 10 触地蒜种盒受力分析

Fig.10 Force analysis of garlic box when falling to ground

由图 10 可知

$$F_1 + F_2 \cdot \cos \alpha = G + F_3 \cdot \sin \alpha, \quad (13)$$

$$F_f = F_2 \cdot \sin \alpha + F_3 \cdot \cos \alpha, \quad (14)$$

式中 F_f 为蒜种盒不发生滑动所需地面提供的摩擦力, N。

$$F_2 \cdot L \cdot \cos \alpha \cdot \cos \theta + F_2 \cdot L \cdot \sin \alpha \cdot \sin \theta = \frac{1}{2} G \cdot L \cdot \cos \theta + F_3 \cdot L \cdot \sin(\alpha - \theta), \quad (15)$$

$$F_3 = \mu_2 \cdot F_2 + \mu_2 \cdot G \cdot \cos \alpha + G \cdot \sin \alpha, \quad (16)$$

$$F_{m1} = \mu_1 \cdot F_1. \quad (17)$$

则

$$F_{m1} - F_f = \mu_1 \cdot F_1 - (F_2 \cdot \sin \alpha + F_3 \cdot \cos \alpha). \quad (18)$$

考虑到试验台的结构尺寸和实用性, 取 $25^\circ \leq \alpha \leq 35^\circ$

当 $\alpha=35^\circ$ 时, 化简得:

$$F_{m1} - F_f = G \left(2.324 - \frac{6.058 \cos \theta - 5.016 \sin \theta}{\cos \theta + 3.161 \sin \theta} \right). \quad (19)$$

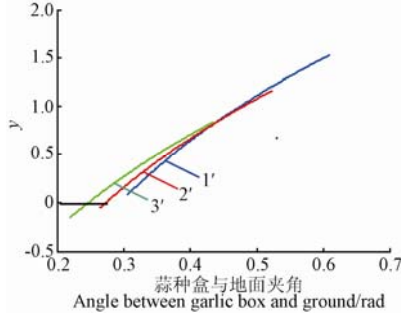
当 $\alpha=30^\circ$ 时,

$$F_{m1} - F_f = G \left(2.079 - \frac{4.545 \cos \theta - 4.212 \sin \theta}{0.972 \cos \theta + 2.316 \sin \theta} \right). \quad (20)$$

当 $\alpha=25^\circ$ 时,

$$F_{m1} - F_f = G \left(1.837 - \frac{2.155 \cos \theta - 2.268 \sin \theta}{0.582 \cos \theta + 1.116 \sin \theta} \right). \quad (21)$$

令 $F_{m1} - F_f = G \cdot y$, y 与 θ 的关系如图 11 所示。



注: 曲线 1'、2'、3' 分别表示输送带倾角为 35° 、 30° 、 25° 时在区间 $[\alpha/2, \alpha]$ 内 y 值随蒜种盒与地面夹角的变化规律。

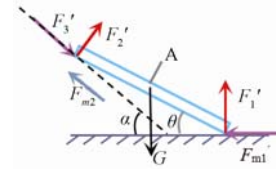
Note: Curves 1', 2', 3' express respectively the change law of y when angle between garlic box and ground is at $[\alpha/2, \alpha]$ as belt angle is 35° , 30° , 25° .

图 11 y 随蒜种盒与地面夹角 θ 的变化

Fig.11 Relationship between y and θ

$y \geq 0$ 时, 蒜种盒与地面不产生滑动, 由图 11 可知, 输送带与地面夹角 θ 越小, y 值越小, 蒜种盒越易与地面产生滑动, 这主要是因为 F_3 的水平分力增大造成的。

以输送带倾角 30° 为例, 分析蒜种盒不产生滑动的条件。由图 11 可知, 蒜种盒与地面夹角约 15° 时, $y < 0$, 此时蒜种盒与地面产生滑动。为避免蒜种盒滑动, 将导向板向上加长以消除输送带对蒜种盒的摩擦力, 导向板与输送带衔接处在蒜种盒倾角为 16° 的位置。当 $\theta \in [15^\circ, 16^\circ]$ 时, 蒜种盒受力如图 12 所示。



注: F_1' 为导向板调整后地面对蒜种盒的支撑力, N; F_2' 为导向板调整后输送带对蒜种盒的支撑力, N; F_3' 为导向板调整后输送带对蒜种盒的摩擦力和上面蒜种盒对该蒜种盒的挤压力, N; F_{m1}' 为地面对蒜种盒的摩擦力, N; F_{m2}' 为导向板对蒜种盒的摩擦力, N。

Note: F_1' expresses the supporting force that ground effects on garlic after garlic plate adjusting, N; F_2' expresses the supporting force that belt effects on garlic after garlic plate adjusting, N; F_3' expresses the sum of friction force that belt effects on garlic and extrusion force that above garlic box effects on lower garlic box after garlic plate adjusting, N; F_{m1}' expresses the friction force that ground effects on garlic box after garlic plate adjusting, N; F_{m2}' expresses the friction force that garlic plate effects on garlic box after garlic plate adjusting, N.

图 12 导向板调整后蒜种盒受力分析

Fig.12 Force analysis of garlic box

试验测得蒜种盒与导向板 (钢板) 摩擦系数为 $\mu_2' = 0.843$, 同理可得

$$F_{m1}' - F_f' = G \left(1.744 - \frac{1.697 \cos \theta - 0.979 \sin \theta}{1.288 \cos \theta - 0.23 \sin \theta} \right).$$

令

$$y' = 1.744 - \frac{1.697 \cos \theta - 0.979 \sin \theta}{1.288 \cos \theta - 0.23 \sin \theta}, \quad (22)$$

y' 与 θ 的关系如图 13 所示。

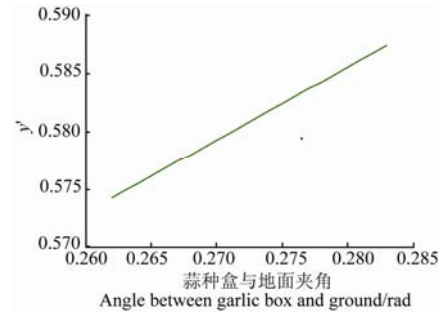


图 13 y' 随蒜种盒与地面夹角 θ 的变化

Fig.13 Relationship between y' and θ

当 $\theta [0, 15^\circ)$ 时,

$$F_{m1}'' - F_f'' = G \left(1.935 - \frac{\cos \theta}{0.946 \cos \theta - 0.169 \sin \theta} \right).$$

令

$$y'' = 1.935 - \frac{\cos \theta}{0.946 \cos \theta - 0.169 \sin \theta}, \quad (23)$$

y'' 与 θ 的关系如图 14 所示。

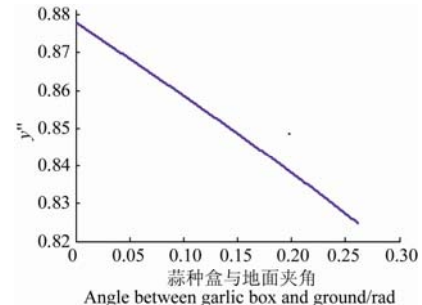


图 14 y'' 随蒜种盒与地面夹角 θ 的变化

Fig.14 Relationship between y'' and θ

由图 13、图 14 可知， y' 、 y'' 均大于 0。

由以上分析可知，通过调整导向板位置，可避免蒜种盒与地面产生滑动。

3 蒜种盒投放试验

为了验证理论分析结果和大蒜播种方案的可行性，制作了蒜种盒投放试验台，如图 15 所示，进行了输送带倾角、试验台运动速度单因素试验^[21-23]和双因素试验。



图 15 蒜种盒投放试验台
Fig.15 Test bed of garlic planter

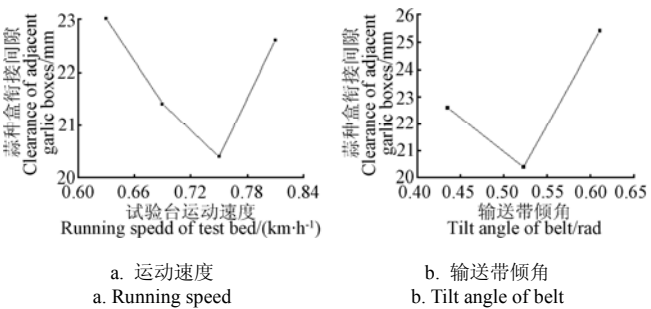
3.1 蒜种盒投放单因素试验

试验因素：输送带倾角，试验台运动速度。
试验指标：投放后蒜种盒衔接间隙。

导向板前端离地面高度约 3.5 mm，蒜种盒落地后的排列样式如图 16 所示。试验台运动速度、输送带倾角对蒜种盒间隙的影响分别如图 17a、17b 所示。



图 16 落地后蒜种盒的排列
Fig.16 Garlic box arrangement after putting



注：试验台运动速度单因素试验，输送带倾角为 30°；输送带倾角单因素试验，试验台运动速度为 0.75 km·h⁻¹。
Note: Tilt angle is 30° on single factor experiment of running speed of test bed; Running speed of test bed is 0.75 km·h⁻¹ on single factor experiment of tilt angle.

图 17 单因素试验结果
Fig.17 Single factor experiment

由图 17 可知，输送带倾角、试验台运动速度对蒜种盒间隙都有影响，但在设定的范围内，蒜种盒间隙的波动幅度很小（<6 mm）。

试验中观察到，蒜种盒的投放效果稳定，蒜种盒与地面未出现滑动现象，设计的方案可行。

3.2 双因素试验

双因素试验方案及结果如表 1 所示，每组试验重复 5 次。方差分析^[24-25]结果如表 2 所示。

表 1 试验方案及结果

Table 1 Design and result of experiment							
试验号 Test number	倾角 Tilt angle of belt C/(°)	速度 Running speed D/(m·s ⁻¹)	投放结果 Results of garlic boxes putting/mm				
1	1(25)	1(0.63)	20	25	25	29	25
2	1	2(0.69)	24	25	20	21	25
3	1	3(0.75)	24	24	24	21	20
4	2(30)	1	18	23	26	26	22
5	2	2	24	20	19	19	25
6	2	3	26	18	17	21	20
7	3(35)	1	35	26	23	21	24
8	3	2	21	26	22	26	25
9	3	3	24	22	27	21	33
K_{1j}	352	372					
K_{2j}	324	342					
K_{3j}	376	342					

表 2 方差分析表

Table 2 Table of variance analysis					
方差来源 Variance sources	偏差平方和 Square of deviance S	自由度 Freedom f	平均方差 Average variance S/f	F 值 F value	$F_{(1-\alpha)}$
C	90.311	2	45.156	3.708	$F_{(1-0.01)}=5.12$
D	30.044	2	15.022	1.234	$F_{(1-0.05)}=3.21$
C×D	9.822	4	2.456	0.202	$F_{(1-0.1)}=2.44$
e	438.4	36	12.178		
T	568.578	44			

由表 1 可知，影响蒜种盒间隙的因素的主次顺序为输送带倾角 C、试验台运动速度 D；试验最优组合为 C₂D₃，相邻蒜种盒平均衔接间隙最小，为 20.4 mm。

由表 2 可知，输送带倾角 C 对指标的影响显著。

根据试验结果，对蒜种盒进行优化，将蒜种盒两端各去掉 10 mm，然后进行正交试验的 C₂D₃ 组合试验，结果如表 3 所示，平均衔接间隙为 1.4 mm，蒜种盒投放效果好。

表 3 蒜种盒优化后试验结果

Table 3 Test results after garlic box optimizing										
试验次数 Test times	1	2	3	4	5	6	7	8	9	10
蒜种盒衔接间隙 Clearance of adjacent garlic boxes/mm	2	0	0	5	0	1	0	2	1	3
均值 Average	1.4									

4 结论与讨论

1) 提出了分段播种的种盒式大蒜播种方案，设计了可降解蒜种盒，事先将蒜种预植于蒜种盒，并采用倾斜输送带式投放装置实施田间投放，实现大蒜的直立播种。

2) 确定了蒜种盒投放过程的技术参数，进行了运动学和动力学分析，明确了主要参数间的相互关系和变化规律，建立了蒜种盒间隙的数学模型，确定了避免产生蒜种盒相对地面滑动的条件。

3) 进行了蒜种盒投放试验, 结果表明, 输送带倾角为 30° 、试验台运动速度为 0.75 km/h , 投放效果较好。通过优化蒜种盒长度两端尺寸, 可以有效消除蒜种盒间隙, 保持播种株距稳定。

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Kinematic analysis and parameter optimized experiment of garlic box putting process

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Abstract: Garlic is one of the major cash crops in China. Because of the special requirements of garlic planting, for which there isn't mature machine at home and abroad, and garlic planting is still done by worker. According to the fact that the planting state of garlic, this paper designed the garlic box and garlic planting test bed with tilt conveying belt. The garlic box was made of degradable protection material such as waste paper pulp and plant straw. The test bed consisted of frame, tilt conveying belt, guiding device, adjustable speed motor, transmission system, pulley, axle of pulley, ground wheel, angle adjusting device of tilt conveying belt, and so on. The garlic planting test bed was powered by adjustable speed motor. According to the garlic box dropping requirements end to end, the transmission ratio between conveyor belt and planting test bed was determined and its value was 1. When the test bed worked, the garlics were put into the garlic box by worker or machine at first, and the boxes were then put on the tilt conveying belt and conveyed to the ground. This paper analyzed the conveying process of the garlic box, and established the mathematical and graphic model about moving velocity of garlic box and clearance of adjacent garlic boxes. The result showed that the clearance of adjacent garlic boxes decreased first and then increased with the tilt angle of belt rising, and the relationship between the clearance of adjacent garlic boxes and the guide plate was positive correlation as the tilt angle of conveying belt was the fixed value. This paper also researched the force condition of garlic box when dropping, made clear the relative motion state between garlic and ground, and analyzed the conditions that could avoid relative sliding between garlic box and ground taking the 30° tilt angle of belt as the example. The analysis result showed the garlic box slid along the belt and the sliding could be avoided by adjusting the connecting position between guide plate and conveying belt to the one with the tilt angle of 16° between garlic box and ground. The result of single-factor experiment showed the test bed could work accurately and reliably, and it could satisfy the requirements of garlic box dropping; the tilt angle of belt and the velocity of test bed had effects on the clearance of adjacent garlic boxes, and the fluctuation range of the clearance of garlic boxes was very small (< 6 mm); the best conditions were the 30° angle of tilt conveying belt and the speed of test bed of 0.75 km/h respectively, under which garlic box did not slide during the experiment. The result of two-factor test indicated the tilt angle of conveying belt had significant effect on the clearance of adjacent garlic boxes, the order of the factors impacting the clearance of garlic boxes was tilt angle of conveying belt > running speed of test bed, and the best test combination for garlic box dropping was the angle of tilt conveying belt of 30° and the velocity of test bed of 0.75 km/h, under which the clearance of adjacent garlic boxes was 20.4 mm; the garlic boxes could be well connected as they were subtracted by 10 mm at the 2 ends of the box.

Keywords: agricultural machinery; kinematics; belts; garlic; garlic box; planting test-bed