温室缀铝膜保温幕节能性能的实验研究初报

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摘 要: 用国产缀铝保温膜幕在温室内进行了保温节能实验。测定比较了有、无保温幕二种情况下的室内气温, 结果表明, 在该实验条件下, 采用缀铝膜保温幕时温室内外温差提高了3～5℃, 保温幕上、下40 cm 处温差平均达到8.8℃。测定了温室有、无保温幕时的供暖量, 并计算了屋面传热系数, 得出缀铝膜保温幕的节能率达到37%, 保温性能良好。

关键词: 温室; 缀铝膜; 保温幕; 节能
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镀铝膜材料表面具有高反射、低发射的辐射特性, 用其编织成的缀铝膜保温幕能有效反射室内向外的长波辐射, 减少热损失, 具有良好的保温节能效果。目前缀铝膜保温幕已在连栋温室中得到普遍应用。为了正确地设计和使用缀铝膜保温幕系统以及准确地计算温室的供暖负荷, 需要准确定量地掌握其保温性能及其影响因素。一些国外研究者和生产厂商虽提供有相关资料, 但因各种缀铝膜保温幕产品的性能不同和使用中的不同设置情况、不同气候条件等多方面复杂因素影响, 对国产缀铝膜在实际使用中的效果, 还缺少准确定量的可靠数据资料。对于缀铝膜保温幕节能率的理解目前也还存在模糊不清的情况。国内周长吉等通过对使用和未使用瑞典产缀铝膜保温幕的温室内气温状况的比较测定[1], 初步估计了缀铝膜保温幕的保温效果。文献[1]所得出的节能率是按温室整体的综合传热系数推定的, 有待更准确地进行实验分析。

本文采用实际测定有、无缀铝膜保温幕条件下温室供暖量的方法, 以便直接和准确地分析缀铝膜保温幕的节能效果。

实验采用上海农园绿色工程公司研制的第二代缀铝膜保温幕。该保温幕由镀铝膜条和PE透明薄膜条间隔编织而成, 镀铝膜面积比例为66%; 采用双层镀铝膜胶结干复工艺, 镀层防潮性好、牢度高, 膜正反面均有较高的反射率, 价格较国外同类产品低30%以上。

1 实验条件与测试方案

1.1 实验温室概况

实验于2000年2月22日至2月29日在北京市顺义"三高"农业示范区的华北型连栋塑料温室内进行。温室檐高2.8 m, 脊高4.5 m。东西方向共8连栋, 单栋跨度为8 m, 南北方向11个开间, 每开间3 m, 温室东西长64 m, 南北宽33 m, 面积2 112 m^2。该温室屋顶与侧墙采用双层充气薄膜覆盖, 南山墙为中空PC板, 北山墙为保温蓄热性能良好的砖墙。温室内上部采用缀铝膜活动式内保温幕覆盖, 保温幕沿跨度方向开闭。

1.2 实验测试方案

测定温室在缀铝膜保温幕覆盖和无覆盖(以下简称有幕与无幕)二种情况下, 温室的供暖量、室内热环境状况以及室外气象条件。

每天白天从7:00至18:00每间隔1 h测定室外气温及太阳光照度, 夜间从19:00至次日6:00每间隔1 h测定温室内的气温, 采暖系统的热水流量, 给、回水温度以及室外气温、风速。

分别在温室内东、西和中部距地面1.5 m高度的地方共布置9个测点, 测定温室内的平均气温(见图1); 在东第2跨和西第2跨距南北侧墙16.5 m处取垂直断面, 共布置测点26×2=52个, 测试温室垂直断面的温度分布(见图2); 在室内的采暖系统供水管路的进水管和回水管处, 分别设置温度表和流量计, 测试采暖系统的给水、回水温度和流量; 在距温室北墙5 m、离地面1 m高处测定室外气温。

2 实验结果与分析

2.1 室外气象条件

经过对多次测定数据的整理和分析, 发现2月26日7时～2月27日6时(有幕)和2月27日7时～2月28日6时(无幕)的二个实验时间段内室外

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气象条件基本一致。二个实验时间段内均为晴天，2 月 26 日 7 时～2 月 27 日 6 时白昼室外平均气温为 8.7℃，平均光照度为 49 500 lx，夜间室外平均气温为 -1.8℃，室外平均风速为 0.9 m/s；2 月 27 日 7 时～2 月 28 日 6 时白昼室外平均气温为 9.1℃，平均光照度为 51 300 lx，夜间室外平均气温为 -1.6℃，室外平均风速为 1.0 m/s。且室外温度变化曲线非常接近(图 3)。

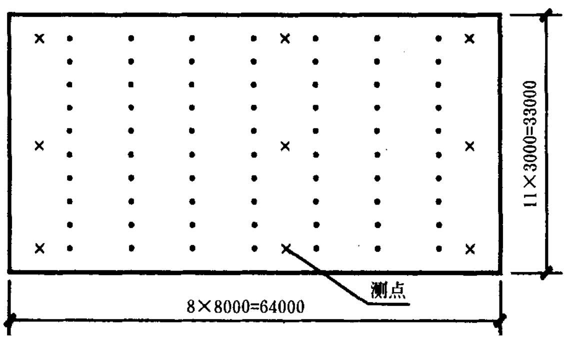

图 1 室内气温测点布置

Fig. 1 Layout of horizontal temperature measuring points

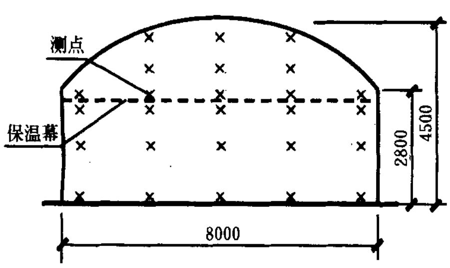

图 2 垂直断面气温测点分布

Fig. 2 Layout of vertical temperature measuring points

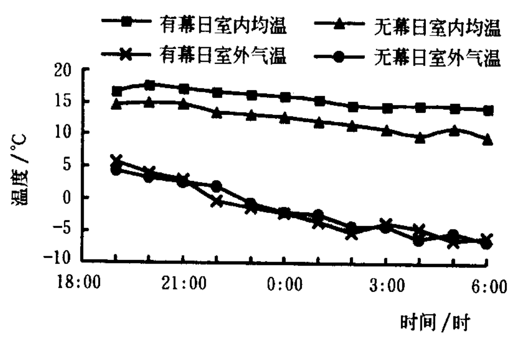

图 3 有幕和无幕时的室内气温状况

Fig. 3 The air temperature outside and inside greenhouse with and without thermal screens

2.2 温室夜间的室内气温和湿度

图 3 是有、无保温幕条件下的室内温度状况，可以看出，有幕的室内温度变化比较平缓、稳定，而无幕的室内温度的变化波动稍大。有幕时室内外温差较无幕时平均高 3～5℃。

保温幕上、下的温差是表明其保温性能的一个重要指标，温差大，保温效果好。由图 4 可知，在夜间保温幕关闭时，幕上幕下温差保持在 7～10℃，平均温差为 8.8℃。而夜间无保温幕与有保温幕时在相同的测点温差很小，最大温差不超过 1.5℃，平均温差仅为 0.9℃，说明保温幕的效果是很显著的。

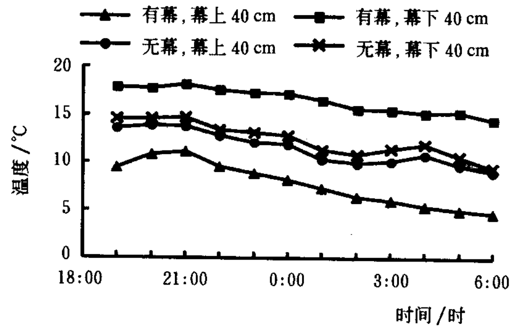

图 4 幕上、幕下温度比较

Fig. 4 The air temperature over and under the thermal screens

2.3 屋面覆盖层的传热系数

保温幕保温效果的定量评价通常采用节能率这一指标，其物理意义是因设置保温幕而减少的温室屋面散热量与无保温幕时温室屋面散热量之比值，可用传热系数的降低值与无保温幕时温室屋面传热系数的比值进行计算。即：

$$\text{节能率} = \frac{\text{无保温幕的传热面传热系数} - \text{有保温幕的传热面传热系数}}{\text{无保温幕的传热面传热系数}} \qquad (1)$$

应当指出的是，保温幕节能率应是针对其对应的温室覆盖面而不是按温室整体进行计算，是表明其对所覆盖保温的传热面减少散热量的程度。温室的总热损失中不仅有通过保温幕和其对应覆盖面的热损失，还包括通过无保温幕的围护结构部分如侧墙等以及通过冷风渗透、地中传热等热损失。按温室整体计算，实质上相当于将保温幕节能效果均摊在包括保温幕未覆盖部分的温室全部散热部位上，得出的节能率偏低。

因此，本文确定缀铝膜保温幕节能率的方法是，分别测定有、无保温幕时采暖系统的热水流量和给、回水温度，计算温室的采暖量，扣除通过地面、侧墙和冷风渗透的热损失，分别得到有、无保温幕时通过屋面的散热量，据此计算其传热系数，最后按(1)式计算节能率。

2.3.1 温室采暖系统的采暖量 Q [3]

$$Q = \rho q_v c (t_1 - t_2)/3600 \quad \text{kW} \qquad (2)$$

式中 ρ —— 水的密度，kg/m³；取 983 kg/m³(水温 60℃)；q_v —— 热水流量，m³/h；c —— 水的比热，

取 4.18 kJ/(kg·℃); t_1—— 给水温度, ℃; t_2—— 回水温度, ℃。

2.3.2　地中传热量 Q_s[2]

$$Q_s = 2K_sA_s(t_i - t_o)/1000 \quad kW \tag{3}$$

式中　K_s—— 地中传热系数, W/(m²·℃), 计算点与外围护结构间的距离 $b <$ 10 m 时, 取 0.233 W/(m²·℃), $b =$ 10～20 m 时, 取 0.116 W/(m²·℃); A_s—— 温室地面面积, m²; t_i—— 室内气温, ℃; t_o—— 室外气温, ℃。

2.3.3　四周墙面传热量 Q_w[2]

$$Q_w = 2K_wA_w(t_i - t_o)/1000 \quad kW \tag{4}$$

式中　K_w—— 侧墙的传热系数, W/(m²·℃), 南墙 (PC 板) 与东西侧墙 (双层充气膜) 取 4 W/(m²·℃); 北墙及东、西、南墙的下部 240 mm 厚砖墙部分, 取 2.14 W/(m²·℃), 南、北墙的湿帘和风机在实验时均用 PE 膜密封, 传热系数按双层充气膜取 4 W/(m²·℃); A_w—— 墙面积, m²。

2.3.4　冷风渗透热损失 Q_v[3]

$$Q_v = \rho L c_p(t_i - t_o) \quad kW \tag{5}$$

式中　ρ—— 空气密度, kg/m³, 取 1.2 kg/m³; L—— 冷风渗透量, m³/s, 按渗透换气次数 1 次/h 计算; c_p—— 空气比热, 取 1.01 kJ/(kg·℃)。

2.3.5　屋面覆盖层的散热量 Q_r 及传热系数 K_r

$$Q_r = Q - Q_s - Q_w - Q_v \quad kW \tag{6}$$

$$K_r = \frac{Q_r}{A_r(t_i - t_o)} \times 10^3 \quad W/(m^2·℃) \tag{7}$$

式中　A_r—— 温室屋面的面积。

根据测得的温室有幕和无幕时采暖系统运行参数及室内外气温, 计算出温室夜间逐时的供暖量、各部分热损失和屋面的传热系数, 见表 1、表 2。

表 1　有保温幕时屋面的传热系数 (2 月 26 日～2 月 27 日)

Table 1　The overall heat transfer coefficient of the roof with thermal screens (Feb. 26～27, 2000)

时间	t_o/℃	t_i/℃	$t_1 - t_2$/℃	q_v/(m³·h⁻¹)	Q/kW	Q_w/kW	Q_s/kW	Q_v/kW	Q_r/kW	K_r/(W·(m²·℃)⁻¹)
19:00	5.6	16.6	21.5	6.54	160.5	24.7	4.7	30.8	100.3	3.84
20:00	3.9	17.6	24.5	6.55	183.2	30.8	5.8	38.4	108.2	3.32
21:00	2.8	17.1	25.0	6.56	187.2	32.1	6.1	40.0	108.9	3.21
22:00	-0.4	16.6	27.0	6.57	202.5	38.2	7.2	47.6	109.5	2.71
23:00	-1.3	16.2	27.5	6.55	205.6	39.3	7.4	49.0	109.8	2.64
0:00	-2.2	15.9	29.5	6.59	221.9	40.7	7.7	50.7	122.9	2.86
1:00	-3.6	15.4	30.0	6.61	226.3	42.7	8.1	53.2	122.4	2.71
2:00	-5.2	14.6	32.0	6.62	241.8	44.5	8.4	55.4	133.5	2.84
3:00	-3.8	14.4	29.0	6.60	218.5	40.9	7.7	51.0	118.9	2.75
4:00	-4.5	14.6	30.5	6.63	230.8	42.9	8.1	53.5	126.3	2.78
5:00	-6.4	14.3	31.0	6.66	235.7	46.5	8.8	58.0	122.4	2.49
6:00	-6.0	14.2	31.5	6.65	239.1	45.4	8.6	56.6	128.6	2.68
平均										2.90

表 2　无保温幕时屋面的传热系数 (2 月 27 日～2 月 28 日)

Table 2　The overall heat transfer coefficient of the roof without thermal screens (Feb. 27～28, 2000)

时间	t_o/℃	t_i/℃	$t_1 - t_2$/℃	q_v/(m³·h⁻¹)	Q/kW	Q_w/kW	Q_s/kW	Q_v/kW	Q_r/kW	K_r/(W·(m²·℃)⁻¹)
19:00	4.2	14.5	24.0	6.78	185.7	23.1	4.4	28.8	129.4	5.29
20:00	3.2	14.9	26.5	6.79	205.4	26.3	5.0	32.8	141.4	5.08
21:00	2.6	14.7	27.0	6.80	209.6	27.2	5.2	33.9	143.4	4.99
22:00	1.8	13.4	25.0	6.81	194.3	26.1	4.9	32.5	130.9	4.75
23:00	-0.6	13.0	28.0	6.81	217.6	30.6	5.8	38.1	143.2	4.43
0:00	-2.0	12.8	30.0	6.83	233.9	33.3	6.3	41.4	152.9	4.35
1:00	-2.3	12.0	29.5	6.84	230.3	32.1	6.1	40.0	152.1	4.48
2:00	-4.2	11.5	32.0	6.85	250.2	35.3	6.7	44.0	164.3	4.40
3:00	-4.3	10.8	30.5	6.85	238.5	33.9	6.4	42.3	155.8	4.34
4:00	-6.2	9.8	33.0	6.87	258.8	36.0	6.8	44.8	171.2	4.50
5:00	-5.2	11.1	33.0	6.87	258.8	36.6	6.9	45.6	169.6	4.38
6:00	-6.6	9.6	32.0	6.88	251.3	36.4	6.9	45.4	162.6	4.23
平均										4.60

2.4 保温幕的节能效果分析

由表 1 与表 2, 温室在无保温幕时屋面平均传热系数为 4.60 W/(m² · ℃), 有保温幕时屋面(包括保温幕) 的平均传热系数为 2.90 W/(m² · ℃), 可得到缀铝膜保温幕的节能率为:

$$节能率= \frac{4.60-2.90}{4.60}\times100\% = 37\%$$

可见缀铝膜保温幕的节能效果是非常显著的。根据国外厂家提供的缀铝膜保温幕性能资料, 其节能率在镀铝膜面积比例为 20%～ 85% 时为 45%～70% , 在与本研究采用的镀铝膜面积比例同为 66% 的情况下, 其节能率为 60%。 但这是在实验室条件下的测定数据, 在实际使用条件下, 由于各保温幕间以及保温幕周边与温室侧墙间存在缝隙, 使保温幕的密闭性降低; 此外室内湿度较大, 将在缀铝膜上产生水汽凝结, 这些因素都可能导致其保温性比实验室理想条件下测定的数据低。

保温幕间以及保温幕周边与温室侧墙间存在缝隙对保温幕的保温节能性的影响程度, 目前尚无定量的测定与分析结论。但因幕上下有近 10℃左右的较大温差, 因密闭不严引起的气流渗透热损失将是不可忽视的。 此外水汽凝结等因素对缀铝膜保温幕性能的影响, 均有待进一步研究, 以便对缀铝膜保温幕系统及产品本身进行改善。

本文仅对镀铝膜比例为 66% 的一种缀铝膜保温幕的使用性能进行了实验研究, 对于不同镀铝膜比例的缀铝膜保温幕的性能, 以及与设计、使用相关的诸多问题, 尚需要今后更多的研究, 以供今后产品改进和系统的设计、使用时参考。

3 结 论

在温室中实验测定结果表明, 缀铝膜保温幕的保温效果显著, 有保温幕时室内外温差较无保温幕时大 3～ 5℃; 通过比较有、无保温幕时的温室供暖量, 得出镀铝膜比例为 66% 的缀铝膜保温幕平均节能率为 37%。 对缀铝膜保温幕系统进行改进完善, 其保温节能效果还将得到进一步提高。

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pneumatic precision planter is carried out and a mathematical model for seed motional locus is established based on which the operation process for plastic film mulch dibbling function is simulated dynamically by use of computer simulation technology, the influence of the change of implement forward speed, seed drop2off2angle and the bias angle of seed receiving funnel on the seed metering accuracy is found out and the relevant parameters are optimized. The results of this research can be taken as a reference for the design of similar implements.
Key words: computerized simulation; pneumatic planter; plastic film mulch planter; seed metering device

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Abstract: Around the sustainable develepment of dryland farming, it has been testing and researching for a long period in the world. The advanced Australian conservation tillage method was introduced in 1991, and was tested in Shanxi Province experimental plots. The test showed that: the conservation tillage has the comprehensive profits of conserving water, improving soil, increasing production and income, and improving ecological envionment. But the planting quality is not so good, which held back further test. Although it can increase the adaption by improving the machine, when the stalk covering rate reaches 80%, a series of problems would appear, e.g. in winter, it is difficult to prevent wind and fire; in spring, the soil temperature goes up slowly, and it is difficult to clean the weeds growing in the crops. By the further test, shallow rotary tillage or shallow harrow of the surface soil, can solve all the problems. Stalk covering, surface soil shallow tillage, and stubble planting make up the matured technical system of conservation tillage method.
Key words: dryland; conservation tillage; surface tillage; sustainable development

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Abstract: According to demands for rice seedlings throwing, the device for raising seedling and seeding in aperture disk was designed and developed. Its working principle and design of rubber belt for conveying seeds were mentioned in the paper. The design scheme was superior after tested by experimentation. Under the condition of superior parameters, best factors combination for seeding in aperture disk with small quantity of seeds can be singled out and optimal seeding perfomance of the device can be obtained.
Key words: raising seedling in aperture sisk; rubber belt for conveying seeds; appending seeds; throwing seeds

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Abstract: The paper introduces an intelligent test system for power and fuel consumption test of small tractors. The system was developed by use of the microelectronics and single chip computer interface technique, based on single chip computer AT89C51 and inspecting the shape of signal wave by technique on dynamic display of data, which came from HBR21 type pressure sensor and HY21 type flow sensor. The measurement accuracy of power is ±0.10% (kW). It can measure power and fuel consumption of small tractors continuously, rapidly and accurately.
Key words: engine; power; fuel consumption; single2chip computer; test

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Abstract: Heat preservation and energy2saving experiment using aluminized thermal screens in greenhouse was conducted. The temperatures inside greenhouse both with and without thermal screens were measured based on experiment. The experimental result showed that air temperature inside greenhouse under aluminized thermal screens can be improved by 3～5℃, and the air temperature at 40 cm above the screen was 8.8℃ higher than that at 40 cm under the screen. According to calulated results of the heating load of the greenhouse and the overall heat transfer coefficient of the roof with and without thermal screens, the average energy saving efficiency reached about 37%, which reveals excellent thermal performance of aluminized thermal sreens.

Key words: greenhouse; aluminized film; thermal screen; energy saving

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Abstract: Based on the contrast analysis of loads provided in foreign and Chinese standards, analysis and discussion are mentioned about the definition and estimation of dynamic wind pressures for multi2span greenhouse structural design in details. Meanwhile, taking advantage of past experience in greenhouse structural design a practical method which can be used in greenhouse design was given for wind load. Under the present conditions, it is unnecessary to make modification of statistical reappearing factor in calculation wind load2dynamic pressure when considering the coefficients of wind pressure depending on height and the gust factor according to Chinese architectural structure load standards (GBJ9287).

Key words: greenhouse; dynamic pressure; structural design

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Abstract: In order to improve the environmental conditions of tissue culture in vitro and to investigate the function of CO_2 in the culture, a CO_2 enrichment and real2time control system was developed. Using this system, the growth experiment of subcultured grape (cabernet sauvignon) plantlets was carried out as compared with the traditional tissue culture method (non2CO_2 enrichment). The results indicated that the system worked well, the required ranges of CO_2 concentration [(800～1 200) LL öL] could be obtained; and the CO_2 enrichment environment could promote the growth and photoautotrophic capability of the plantlets in vitro.

Key words: CO_2 enrichment; real2time control; biological environment; tissue culture; sucrose2free culture

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Abstract: Responses of physiological parameters and activity to humidity and temperature were studied using DSI animal physiological parameters on2line telemetry system and environmental condition and animal activity detecting system. The results show that body temperature, heart rate of pigs raised under high room temperature in summer, and swine growing performance decreased, especially, under high humidity and temperature. a 10 % increase in relative humidity was offset by 1℃ decrease in ambient