Research article

Survey Analysis of the Characteristics of Greenhouses in Korea

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Abstract The purpose of this study is to collect basic data (using a questionnaire survey) to inform the establishment of structural safety guidelines and the standardization of greenhouse design in order to determine a standard model for the development of greenhouses on reclaimed land. To collect this data, 148 farms were visited across Korea, and were administered a questionnaire survey. The survey included items on greenhouse facilities, foundations, covering material, and irrigation type. Results revealed that greenhouses were nearly evenly split between single- and multi-span structures. Most were arch or 1-2W types. Single-span greenhouses tended to use pipe foundations, while most multi-span greenhouses used concrete foundations, and most foundations were buried deeply (50-59 cm). Nearly all greenhouses (95.3%) used plastic film as a covering material as opposed to glass; the same percentage used groundwater for irrigation. These results could potentially be utilized as basic data to develop a standard model for greenhouse design in Korea.

Keywords greenhouse structure, greenhouse covering material, greenhouse foundation, survey data, greenhouse irrigation

INTRODUCTION

The total area dedicated to greenhouse cultivation of vegetables in Korea occupied about 47,924 ha at the end of 2012 (MAFRA, 2013). This area is expected to increase gradually in the future following the Korean government's announcement of a development plan to build a research center on reclaimed land in Saemangeum, an estuarine tidal flat on the Yellow Sea coast. The construction of a seawall in April 2006, after a long fight between the government and environmental activists, allowed the land to be reclaimed. Since the establishment of the seawall, Saemangeum has been scheduled for conversion into either agricultural or industrial land (Choi et. al., 2013). As such, the planned research center is slated to incorporate a high-tech greenhouse and large-scale agricultural complex that covers a large percentage of the reclaimed land. Additionally, a greenhouse is currently under development at other reclaimed land at Hwang (MIFAFF, 2010).

When building a greenhouse on reclaimed land, land settlement, structures and potentially dangerous exposure to strong wind should be considered, because reclaimed land (due to its proximity to the coast) is softer than general farmland. In considering the characteristics of reclaimed land, there are many greenhouse construction requirements with regard to maintenance, repair, reinforcement, structural design criteria, and deformation.

Many studies have investigated the actual conditions of various greenhouses. Suh and Yoon conducted a survey analysis that collected data on heating method, gutter connection, capacity of heating systems, type of crop cultivation, dimensions, etc. (Suh and Yoon, 1997). Studies have also

been conducted on the actual state of the structures and environmental control facilities for tomato greenhouses in the Chungnam region (Nam and Kim, 2009), as well as on the utilization of irrigation systems for greenhouse farming (Lee et al., 1998). However, to date, no one has yet conducted a nationwide study of greenhouses in Korea.

OBJECTIVE

This study's aim is to provide basic data for the development of greenhouse maintenance guidelines. This was accomplished by conducting a questionnaire survey on the structure, covering materials, irrigation, and foundations of greenhouses in Korea.

METHODOLOGY

A questionnaire survey was conducted to investigate the actual state of greenhouses in Korea. Regional investigations were conducted in eight of Korea's nine provinces (Jeju was excluded). Most greenhouses were selected and investigated via Agricultural Research Services, while large, complex greenhouses were examined using satellite images. Greenhouses on a total of 148 farms were investigated (Fig. 1): 63 for Gyeongsangnam-do (Gyeongnam); 15 for Jeollanam-do (Chonam); 11 for Kangwon-do (Kangwon); 10 for Gyeonggi-do (Gyeonggi), 10 for Chugcheongbuk-do (Chungbuk), 10 for Chugcheongnam-do (Chungnam); 10 for Jeollabuk-do (Chonbuk); and 19 for Gyeongsangbuk-do (Gyeongbuk). The following aspects of each greenhouse were investigated: type, specifications, foundation type, irrigation type, and depth of foundation. Additionally, questionnaire surveys were conducted during farm visits from July to September 2013. Survey data were analyzed using SPPS (IBM SPSS Statistics Version 20).

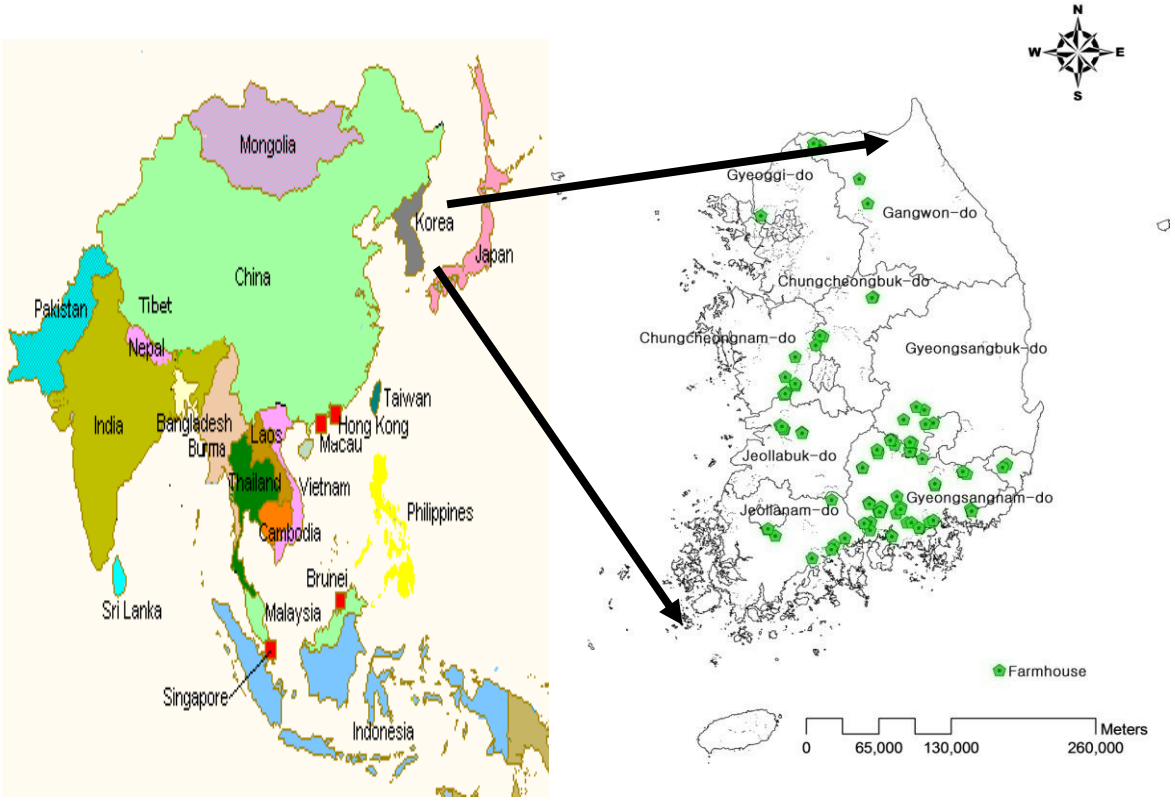

Fig. 1 Locations of surveyed greenhouses

RESULTS AND DISCUSSION

Of the 148 farms investigated, a total of 148 valid questionnaires were received. Data collected from these questionnaires were analyzed using SPSS.

Greenhouse Types

Figure 2 shows the number and percentage of single- vs. multi-span greenhouses 72 (48.6%) for the former, and 76 (51.4%) for the latter. Table 1 shows the types of greenhouses investigated. According to the survey, 51 (34.5%) for arch greenhouses, 56 (37.8%) were 1-2W, 11 (7.4%) were Venlo, 6 (4.1%) were Miryang, 3 (2.0%) were three-quarter, 1 (0.7%) were even-span, 2 (1.4%) were peach-type, 6 (4.1%) were long-span, and 12 (8.1%) were other, respectively ("Other" includes greenhouses without columns, Mammoth-type greenhouses, and so on). The most common type of greenhouse was the 1-2W, which, along with the arch type, accounted for 72.3% of all surveyed greenhouses. The even-span type was the least common, accounting for less than 1.0% of all surveyed greenhouses. From this result, it is clear that most farms in Korea prefer the arch style for single-span greenhouses, and the 1-2W style for multi-span greenhouses.

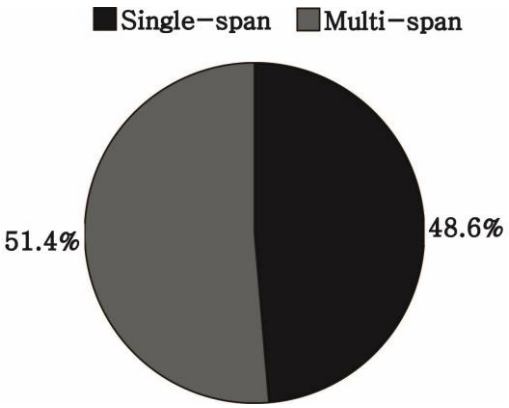

Fig. 2 Percentage of single- vs. multi-span greenhouses

Table 1 Types of greenhouse by region

Classifications	Type									Total
	Arch type	1-2W type	Venlo type	Miryang type	3/4 roof type	Even type	Peach type	Long span type	Others	
Gyeongnam	21	22	5	6	3	1	0	2	3	63
Chonnam	0	6	4	0	0	0	0	3	2	15
Kangwon	2	2	0	0	0	0	2	0	5	11
Gyeonggi	0	8	2	0	0	0	0	0	0	10
Chungbuk	5	5	0	0	0	0	0	0	0	10
Chungnam	7	2	0	0	0	0	0	0	1	10
Chonbuk	4	6	0	0	0	0	0	0	0	10
Gyeongbuk	12	5	0	0	0	0	0	1	1	19
Total	51	56	11	6	3	1	2	6	12	148
(%)	(34.5)	(37.8)	(7.4)	(4.1)	(2.0)	(0.7)	(1.4)	(4.1)	(8.1)	(100.0)

Foundation Type

Table 2 shows the results for foundation type according to region. The survey found that 47 (31.8%) greenhouses used pipes, 25 (16.9%) used strip foundation of pipe (surface), 8 (5.4%) used strip foundation of pipe (inner), 16 (10.8%) used concrete (trapezium), 24 (16.2%) used concrete

(columns), 18 (12.2%) used concrete (THP), and 10 (6.8%) used other foundation types. Further, it is apparent that foundation type is related to greenhouse type: single-span greenhouses tended to feature any of the three types of pipe foundation (pipes burial, strip foundation of pipe (surface), and strip foundation of pipes (inner)), while multi-span greenhouses tended to feature any of the three types of concrete foundation (trapezium, columns, and THP). Of the 148 greenhouses investigated, nearly half used one of the three types of pipe foundation (commonly associated with single-span greenhouses); this is likely because single-span greenhouses are easier and cheaper to install than multi-span greenhouses. After pipes burial (31.8%), the most popular type of non-pipe foundation was concrete (columns) at 16.2%. Regional characteristics that could account for these preferences were not observed.

Depth of foundation results by region shows in Table 3. The survey found that 6 (4.1%) foundations were buried < 30 cm, 17 (11.5%) were 30-39 cm, 27 (18.2%) were 40-49 cm, 53 (35.8%) were 50–59 cm, 33 (22.3%) were >= 60 cm and 12 (8.1%) for other, respectively. Of the greenhouses surveyed, most (53, or 35.8%) had foundations buried 50-59 cm deep. For most greenhouses in general, which factor a wind speed of up to 30m/s into their design, 30 cm is a sufficient foundation depth. However, regions with wind speeds of at least 40 m/s have been reported to require a foundation embedment depth of at least 50 cm (Kim and Nam, 1995). Thus, greenhouse designs must take regional wind speeds into account. In all cases, the embedment depth was determined to be appropriate to regional wind speed, except those foundations buried 30 cm deep or less in Gyeongnam and Chonnam provinces.

Table 2 Types of foundation by region

Classifications	Types of foundation							Total
	Pipes burial	Strip of pipe (surface)	Strip of pipes (inner)	Concrete (trapezium)	Concrete (columns)	Concrete (THP)	Others	
Gyeongnam	27	6	0	7	9	8	6	63
Chonnam	1	0	2	2	6	2	2	15
Kangwon	6	1	0	1	1	2	0	11
Gyeonggi	1	4	1	0	3	1	0	10
Chungbuk	1	4	2	0	2	1	0	10
Chungnam	2	5	0	0	0	1	2	10
Chonbuk	0	1	3	2	2	2	0	10
Gyeongbuk	9	4	0	4	1	1	0	19
Total	47	25	8	16	24	18	10	148
(%)	(31.8)	(16.9)	(5.4)	(10.8)	(16.2)	(12.2)	(6.8)	(100.0)

Table 3 Depth of foundation embedment by region

Classifications	Embedment depth						Total
	<30cm	30~39cm	40~49cm	50~59cm	>=60cm	Others	
Gyeongnam	5	4	17	18	12	7	63
Chonnam	1	2	1	3	6	2	15
Kangwon	0	2	2	3	4	0	11
Gyeonggi	0	1	1	4	4	0	10
Chungbuk	0	1	0	4	2	3	10
Chungnam	0	1	2	5	2	0	10
Chonbuk	0	0	4	5	1	0	10
Gyeongbuk	0	6	0	11	2	0	19
Total	6	17	27	53	33	12	148
(%)	(4.1)	(11.5)	(18.2)	(35.8)	(22.3)	(8.1)	(100.0)

Covering Material

Table 4 shows the greenhouse covering material by region. The survey found that 141 (95.3%)

greenhouses used plastic film, while 7 (4.7%) used glass. Regardless of region, most installed plastic film, likely because it is far less expensive.

Results regarding greenhouse irrigation type are given in Table 5. The survey found that 141 (95.3%) used groundwater, 5 (3.4%) used stratum water, 1 (0.7%) used a combination of ground and stratum water, 1 (0.7%) used other types of irrigation, and 0 (0.0%) used rainwater. It is interesting to note that the overwhelming majority of greenhouses used groundwater, while none used rainwater.

Table 4 Greenhouse covering material by region

Classifications	Covering materal		Total
	Plastic film	Glass	
Gyeongnam	59	4	63
Chonnam	13	2	15
Kangwon	11	0	11
Gyeonggi	9	1	10
Chungbuk	10	0	10
Chungnam	10	0	10
Chonbuk	10	0	10
Gyeongbuk	19	0	19
Total	141	7	148
(%)	(95.3)	(4.7)	(100.0)

Table 5 Greenhouse irrigation type by region

Classifications	Irrigation water					Total
	Ground water	Rian water	Stratum water	Ground+Stratum water	Othres	
Gyeongnam	61	0	2	0	0	63
Chonnam	15	0	0	0	0	15
Kangwon	8	0	3	0	0	11
Gyeonggi	9	0	0	0	1	10
Chungbuk	10	0	0	0	0	10
Chungnam	10	0	0	0	0	10
Chonbuk	10	0	0	0	0	10
Gyeongbuk	18	0	0	1	0	19
Total	141	0	5	1	1	148
(%)	(95.3)	(0.0)	(3.4)	(0.7)	(0.7)	(100.0)

CONCLUSION

This study presented the results of a detailed questionnaire survey on the types of form, foundation embedment depth, covering material, and irrigation water of greenhouses in Korea. The results obtained can be summarized as follows:

1) Of the 148 farms surveyed, 48.6% used single-span greenhouses, and 51.45% used multi-span.
2) Most greenhouses were the arch or 1-2W type.
3) Most greenhouse foundation types were pipe foundations for single-span greenhouses and concrete foundations for multi-span greenhouses.
4) Embedment depth indicated that 88.4% of surveyed foundations were buried deeper than 40cm.
5) Most of the greenhouses examined (95.3%) used plastic film (PE) as a covering material.
6) Most of the greenhouses (95.3%) irrigated using groundwater.

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