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Short Communication

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Inflorescence appearance timing and production rate traits in wild Zoysiagrass (*Zoysia* spp)

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ABSTRACT

Zoysiagrass (*Zoysia* spp.) has excellent turf quality and can be applied to various uses for personal space to public sports areas or commercial landscapes. However, it has disadvantages such as slow growth rate, cold hardiness, low seed yield, and hard to establish from seeds, which cannot be improved with agricultural practices. Therefore, breeding a new cultivar as a hybrid could be an efficient strategy to improve the Zoysiagrass cultivar. In fact, hybrid zoysiagrass shows mixed traits of both parents in morphology and heterosis in growth. However, inflorescence appearance and its rate are known to make a hybrid. Thus, the variety of inflorescence appearance timing and production rate were investigated among 549 genetic resources. As a result, only 5.38% of the variety among survived zoysiagrass after transplanting showed more than 30% inflorescence appearance within the given period. During that, some varieties showed a reduction of total inflorescence. Hence, we report the diversity of inflorescence appearance timing and production rate that could be useful for breeders and researchers breeding new Zoysiagrass cultivars.

KEYWORDS: Breeding, grass, phenotype, new cultivar, germplasm

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INTRODUCTION

Zoysiagrass (*Zoysia* spp.) is a warm-season turfgrass and C_4 plant. It has a larger adaptable range than other C_4 grasses. It has excellent and beautiful turf quality (Piper, 1921), superior wear tolerance (Lulli *et al*., 2012), good shade tolerance (Qian & Eneelke, 2000). In addition, it is relatively strong at drought (White *et al*., 2001), salt (Beard & Beard, 2005), weed (Fry *et al*., 2008). By these strengths, zoysiagrass is utilized on golf courses, homes, sports fields, and commercial landscapes (McCarty, 2018).

However, it has some shortcomings. Sturkie (1941) reported the slow growth of zoysiagrass. Significantly, the growth delays at an establishment are critical (Carroll *et al*., 1996). Compared with other C_4 turfgrass, for example, bermudagrass, taking the time of planting to sod harvesting is approximately doubled (McCarty *et al*., 1999). Also, the cold hardiness is one of the shortcomings. *Zoysia matrella* showed a variable winter injury response, while some germplasm often does not survive at cold wheater (Forbes, 1952; Patton & Reicher, 2007; Patton *et al*., 2017). Moreover, the seed yield and seed establishment are also a significant disadvantage. Compared with the other two species that 485 to 1066 kg seed ha^{-1} perennial ryegrass (*Lolium perenne* L.) (Niskanen & Nieméläinen, 2007) or 412 to 892 kg seed ha^{-1} common bermudagrass (*Cynodon dactylon* L.) (Ahring *et al*., 1974), zoysiagrass produce about 112 kg seed ha^{-1} per year (Samudio, 1996). And establishing zoysigrass from seed is also very difficult. There are three difficult challenges to establishing zoysiagrass from seed. These are slow germination rate (Patton *et al*., 2004), low seed germination rate (Portz *et al*., 1981), and rapid weed encroachment (Patton *et al*., 2004). However, These difficulties are solved by agricultural treatment. The seed treatment polyethylene glycol priming with KOH before sowing improves germination speed and rates (Han *et al*., 2014). However, the answer for low seed production is limited. By observing 549 genetic resources, we would find the answer.

Also, For breeding a new zoysiagrass cultivar, It is necessary to cross between zoysiagrass varieties easily. Kim *et al.* (1996) reported that the hybrid zoysiagrass variety represented intermediates traits of both parents in morphology and heterosis in growth. To using these characteristics of zoysiagrass, the reproduction process such as inflorescence appearance or production is important. For the plant reproductive, regulation of floral transition and inflorescence development is essential (Cheng *et al*., 2021). Then, secure and accumulate data related to inflorescence is needed.

The objective of the current study is to determine the diversity of inflorescence appearance timing in wild Zoysiagrass (*Zoysia* spp.) species within the given time to see if there is variation in inflorescence appearance timing. The results would be useful for breeders and researchers to understand how diverse wild Zoysiagrass (*Zoysia* spp.) species are so that they would prepare their plans accordingly.

MATERIALS AND METHODS

Plant Material

All experiments were conducted in the greenhouse at Jeju national university. The zoysiagrass used in the experiments was a genetic resource collected from the Forest Life Resources Conservation at Jeju National University. Each genetic resource of zoysiagrass is planted on a 32 hole tray on 29 July 2020 with commercial soil 'Sudoyoug-sang-to'(Nongwoobio Gyeonggi-do, Korea) and 'Bogeumjari-Sudoyoug-sang-to' '(Nongwoobio, Gyeonggi-do, Korea). A total of 549 genetic resources were transplanted. The grass was planted on the side of 32 hole tray and not planted on the center of the tray. The grass was divided by 12 individuals, and only one individual grass was planted in a hole. Watered by sprinkler and for the root survival, watered 40 min every day for a month after transplanting. After that, the watering time was decreased slowly. From October, the dormant period of zoysiagrass, we watered once a week for 1 hour.

Data Collection

The survivability after transplanting data was collected on 1 December 2020, and inflorescence appearance rate and production data were collected on 2,17 and 23 April 2021. Survivability after transplanting is a percentage of survived grass per a total of 12 individual transplanted grass. The inflorescence appearance rate is the inflorescence presence or absence on survived grass. The inflorescence production rate is survived grass per total inflorescence number.

Data Analysis

Collected data was organized by Microsoft Excel (Microsoft Corporation, Microsoft Office Excel, Redmond, WA). Statistical analysis was conducted by the 'R' (R Foundation for Statistical Computing, Vienna, Austria) program. The 'Hmic' package was used for correlation analysis.

RESULTS

Correlation among Survivability, Inflorescence Appearance, and Production

Survival after transplanting has a low correlation with inflorescence appearance and production (Table 1). However, there is a high correlation between inflorescence appearance and production. It means that the many appearances of inflorescence mean much production of inflorescence.

Inflorescence Appearance of Zoysiagrass

Table 2 showed that on first observation, only four entries out of 549 zoysiagrass appeared more than 30% inflorescence. On the second, 21 entries, and the third, 32 entries appeared more

Table 1: Spearman correlation coefficients among survivability, inflorescence appearance, and inflorescence production rate in the zoysiagrass genetic resources

	IA1[a,b]	IA2	IA3	IP2	IP3
SG	-0.09**,[b]	-0.10**	-0.12**	-0.10**	-0.12**
IA1		0.53***	0.41***	0.50***	0.41***
IA2			0.76***	0.99***	0.74***
IA3				0.76***	0.99***
IP2					0.74***

[a]SG = survived grass after transplanting, IA = Inflorescence appearance, IP = Inflorescence production, 1 = First observation at April 2nd, 2 = Second observation at April 17th, 3 = Third observation at April 23rd.
[b]Inflorescence appearance rate is the inflorescence presence or absence on survived grass, and The inflorescence production rate is survived grass per total inflorescence number.
[c]* $P \leq 0.05$, ** $P \leq 0.01$, *** $P \leq 0.001$, n = 549

Table 2: The entry and inflorescence appearance rate of Zoysiagrass (*Zoysia* spp.) appeared more than 30% of inflorescence (among genetic resources, the survival rate is more than 50%) after the transfer of 549 Zoysiagrass genetic resources

Entry	First observation (2 April)	Seconde observation (17 April)	Third observation (23 April)
San 003	91.67[a]	100.00	100.00
San 104	91.67	91.67	0.00
San 088	75.00	75.00	83.33
San 113	25.00	41.67	50.00
San 336	33.33	44.44	66.67
San 155	18.18	45.45	54.55
San 415	22.22	55.56	55.56
San 432	28.57	57.14	57.14
San 361	18.18	36.36	36.36
San 540	18.18	36.36	36.36
San 543	18.18	36.36	36.36
San 162	8.33	33.33	41.67
San 287	10.00	20.00	30.00
San 150	0.00	75.00	75.00
San 063	0.00	50.00	50.00
Aladong	0.00	41.67	41.67
San 154	0.00	41.67	41.67
San 010	0.00	33.33	33.33
San 318	0.00	33.33	33.33
San 457	0.00	44.44	44.44
San 362	0.00	37.50	50.00
San 170	0.00	25.00	33.33
San 106	0.00	25.00	33.33
San 299	0.00	33.33	44.44
San 253	0.00	16.67	41.67
San 093	0.00	16.67	33.33
San 380	0.00	20.00	40.00
San 124	0.00	28.57	42.86
San 374	0.00	9.09	45.45
San 274	0.00	0.00	41.67
San 076	0.00	0.00	41.67
San 290	0.00	0.00	45.45
San 284	0.00	0.00	40.00

[a]Percentage rate of inflorescence appearance is the inflorescence presence or absence on survived grass

than 30% inflorescence. The inflorescence appearance rate is only 0.73%, 3.83%, and 5.83% (Table 3). Partially, the 'San 104', all the inflorescence is disappeared at the third observation. However, in the other three entries, 'San 003', 'San 088', and 'San 336', the inflorescence appearance rate increases to 91.67% to 100, 75.00% to the third observation 83.33%, and 33.33% to 66.67%, respectively. At first observation 'San 150' to 'San 284', these 21 entries did not show inflorescences. Among these entries, 'San150' to 'San374', the inflorescence appears between 2 to 17 April. Also, on the second, from 'San274' to 'San 284', four entries did not show inflorescences. Likewise, these entries appear inflorescence between 14 to 23 April.

Inflorescence Production of Zoysiagrass

Most of the zoysiagrass genetic resources in this study showed increasing inflorescence during three observations. However, 'San 104', 'San 415', 'San 432' and 'San 150' decreased inflorescence. At first observation, 'San 104', 'San 415' and 'San 432' appeared inflorescences, and in the second observation, the inflorescences are increased. And 'San 150' appeared inflorescences. Lastly, in the third observation, the mentioned entries, 'San 104', 'San 415', 'San 432' and 'San 150', decreased inflorescences. 91.67% to 0%, 55.56% to 33.33%, 57.14% to 42.86%, and 100% to 75% respectively (Table 4).

DISCUSSION

Zoysiagrass has many advantages compared with other turfgrass species. It has a low requirement for nutrition and management (Fry *et al*., 2008; Turgeon, 2009). Also, It represents much strength mentioned above. Therefore, despite its shortcomings, such as mentioned above, many breeders and researchers have improved the traits of zoysiagrass. For better new cultivars, there is already effort to make hybrid zoysiagrass on the approximately same flowering time that can cross-pollination (Genovesi & Chandra, 2015). However, there is a lack of data about inflorescence appearance timing and production rate.

In the current study, we report a variety of inflorescence appearance timing and production rate (Table 2-4). In Table 2, the inflorescence appearance rate of the observed zoysiagrass is low. It could be the answer to why the zoysiagrass has low seed production. Also, we conducted the observed traits that are not correlated with survivability after transplanting (Table 1). These observations suggested that the traits related to survival after transplanting are separated from easy inflorescence appearance traits. Then, by hybrid by the other two zoysiagrass with each trait, it could be possible to make the cultivar with good survivability after transplanting and easy inflorescence appearance trait. To efficiently do this, securing Zoysiagrass variety with easy inflorescence appearance traits and data about their inflorescence appearance timing could be essential.

Taken together, this study has two suggestions for efficient and rapid breeding of new zoysiagrass cultivar. First, a zoysigrass with an excellent trait with low survivability; should be crossed with other zoysiagrass with high transfer survivalists for an excellent trait with good transfer survivability. Second, although it has desirable agronomic traits, zoysiagrass with a very low inflorescence appearance rate would have difficulty crossing it with other zoysiagrass.

We found that the inflorescence appearance timing is very different between each zoysiagrass variety. For using a trait

Table 3:. The percentage of Zoysiagrass (*Zoysia*. spp) appeared inflorescence rate of 549 Zoysiagrass genetic resources

	First observation (2 April)	Seconde observation (17 April)	Third observation (23 April)
Inflorescence appearance rate (%)[a]	5.64	19.49	30.42
Survived zoysiagrass inflorescence appearance rate>30% (%)[b]	0.91	3.83	5.83

[a]Inflorescence appearance rate is the inflorescence presence or absence on survived grass
[b]Among zoysiagrass entries surviving more than 50% after transplantation, the percentage of zoysiagrass with an inflorescence appearance rate of more than 30%

Table 4: The entry and inflorescence production rate of Zoysiagrass (*Zoysia* spp.) appeared more than 30% of inflorescence (among genetic resources, the survival rate is more than 50%) after the transfer of 549 Zoysiagrass genetic resources

Entry	First observation (2 April)	Seconde observation (17 April)	Third observation (23 April)
San 003	91.67[a]	308.33	308.33
San 104	91.67	91.67	ND
San 088	75.00	166.67	175.00
San 113	25.00	41.67	50.00
San 336	33.33	55.56	66.67
San 155	18.18	54.55	90.91
San 415	22.22	55.56	33.33
San 432	28.57	57.14	42.86
San 361	18.18	54.55	54.55
San 540	18.18	36.36	45.45
San 543	18.18	45.45	45.45
San 162	8.33	58.33	83.33
San 287	10.00	20.00	30.00
San 150	ND[b]	100.00	75.00
San 063	ND	58.33	66.67
Aladong	ND	66.67	66.67
San 154	ND	50.00	50.00
San 010	ND	50.00	58.33
San 318	ND	50.00	50.00
San 457	ND	44.44	55.56
San 362	ND	37.50	50.00
San 170	ND	25.00	33.33
San 106	ND	25.00	33.33
San 299	ND	33.33	44.44
San 253	ND	16.67	50.00
San 093	ND	16.67	58.33
San 380	ND	30.00	50.00
San 124	ND	28.57	42.86
San 374	ND	9.09	81.82
San 274	ND	ND	41.67
San 076	ND	ND	91.67
San 290	ND	ND	63.64
San 284	ND	ND	50.00

[a]Percentage rate of survived zoysiagrass per inflorescence production.
[b]ND = No data (no inflorescence was observed)

that easy inflorescence appearance, It is necessary to secure and accumulate data on the correct inflorescence timing of each zoysigrass variety. The inflorescence appearance timing and production trait data can be applied as a bridge of accelerating and efficient breeding of excellent trait zoysiagrass cultivar.

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