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# Distribution of $C_4$ Type Grasses in Korea

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# 한국의 $C_4$ 형 식물의 분포 조사

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## 적 요

한국에서의 $C_3$, $C_4$, CAM 식물의 지리적 분포를 알아보았다. 한국 전체에서 258 군데의 지역에서 모든 초본식물들의 목록을 작성하고 각 식물들의 중요값을 통해 우점종을 결정하였으며 이들 식물의 분류에는 크란츠 해부구조의 존재 관찰을 비롯한 여러가지 방법들을 사용하였다.

이 연구의 결과에 따르면 우리나라의 $C_4$ 형 초본식물은 총 7개과 92 종이었으며 $C_4$ 식물의 대부분은 화본과 식물이었다. 대한민국에서의 $C_3$ 와 $C_4$ 형 초본식물의 분포는 초본식물의 서식지와 관련되어 나타났다. 야외 및 해변의 건조지역에서는 $C_4$형 초본과 조건적 CAM 식물이 주로 서식하고 있는 반면, 습윤지역에서는 주로 $C_3$ 형 초본식물이 많이 나타났다. 조사된 총 258 개 지역 중에서 잔디가 우점종인 지역은 6 개 지역이었다.

## INTRODUCTION

Higher plants living on the earth can be classified into $C_3$, $C_4$ and CAM plants by the differences of their photosynthetic pathways. Above-mentioned three photosynthetic forms have different ecological significances considering various environmental factors such as light intensity, temperature, humidity and so on. And these three type of photosynthesis show several different characteristics such as the optimal temperature of photosynthesis, the anatomy of organs that conduct photosynthesis and relationships with water availability.

It is often assumed that the differences of these characters of photosynthesis are the results of adaptation of plants to their specific environments for photosynthesis. $C_4$ plants have received great attention because of the economic importance of some of them and because under high light and warm temperature they can photosynthesize more rapidly and produce substancially more biomass than $C_3$ plants. Investigation of the $C_4$ pathway

have also taught us much about factors that control productivity in various climates.

*Zoysia japonica* is a kind of $C_4$ plant that use the $C_4$-dicarboxylic Acid Pathway in photosynthesis. This study was conducted to know the distribution pattern of the grass floas of Korea, especially that of $C_4$ plants and *Zoysia japonica*.

## MATERIALS AND METHODS

This study was conducted for about three years from April, 1990 to October, 1993. Samples were collected from 258 regions when the whole areas of Korea were divided into 62 quadrats(Fig. 1). The climatic characteristics of each region were recorded. Each collected sample was identified in field in most cases, and in laboratory when needed. The classifications of samples to $C_3$ or $C_4$ type were conducted by several methods ; (1) observation of the Kranz anatomy, (2) electromicroscopical classification, (3) measurements of $CO_2$ compensation points, (4) localization of enzymes, (5) measurements of $^{13}C$, (6) measurements of photorespiration, (7) comparison of the productivity of $C_3$ with that of $C_4$ type grasses.

The complete lists of grasses from 258 regions of Korea were obtained. The dominant species of each region was determined by the importance value calculated. Each habitat was classified and assigned according to its characteristics ; G for grassland, T for tidalland, Rp for rice paddy, R for River, Fl for farmland and F for forest. Species growing only in cultivation were excluded from tabulations.

## RESULTS AND DISCUSSION

It is reported that photosynthetic capacity and light saturation were enhanced under the higher light intensity in $C_3$ and $C_4$ plants (Moss et al. 1961, Hesketh and Moss 1963, and EL-Sharkway and Hesketh 1964). Also optimal temperature for the maximum photosynthetic capacity of $C_4$ plants were remarkably decreased at 15℃~20℃. Under the optimal temperature, light intensity and field capacity for the photosynthetic activities of the plants, the photosynthetic rates of $C_3$ and $C_4$ plants were 10~35 mg $CO_2$ $dm^{-2}hr^{-1}$ and 60~100 mg $CO_2$ $dm^{-2}hr^{-1}$, respectively. Moss(1962) and Forrester et al. (1966) reported that the $C_4$ plants showed lower $CO_2$ compensation points regardless of $O_2$ concentration and release of $CO_2$ gas into air under the light condition.

Of the above-mentioned seven methods, the observation of the Kranz anatomy was the most powerful. Most of the classification in this study were conducted by this method. The anatomical characteristics of $C_4$ plants in Korea showed typical Kranz anatomy ; that is, chloroplast in the vascular bundle sheth cells with starch granules and chloroplasts in the mesophyll cells without starch granules (Smith and Brown, 1973 ; Frederick and Newcomb, 1971). These anatomical points were employed for the morphological identification of $C_3$ and $C_4$ type grasses in this study.

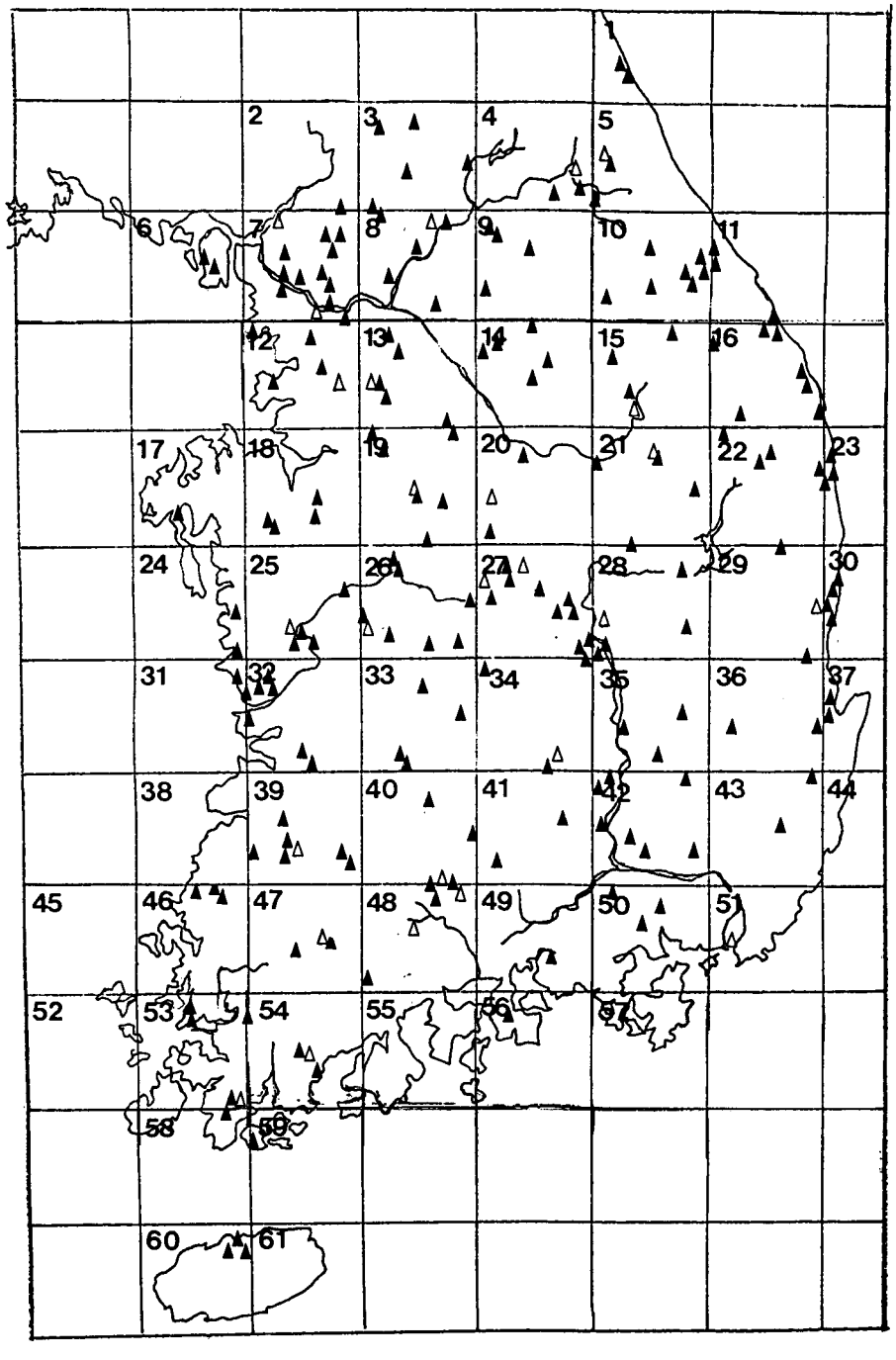


**Fig. 1.** Sampling areas for vegetation analysis by mesh-method. 258 sites in 62 meshes were selected.

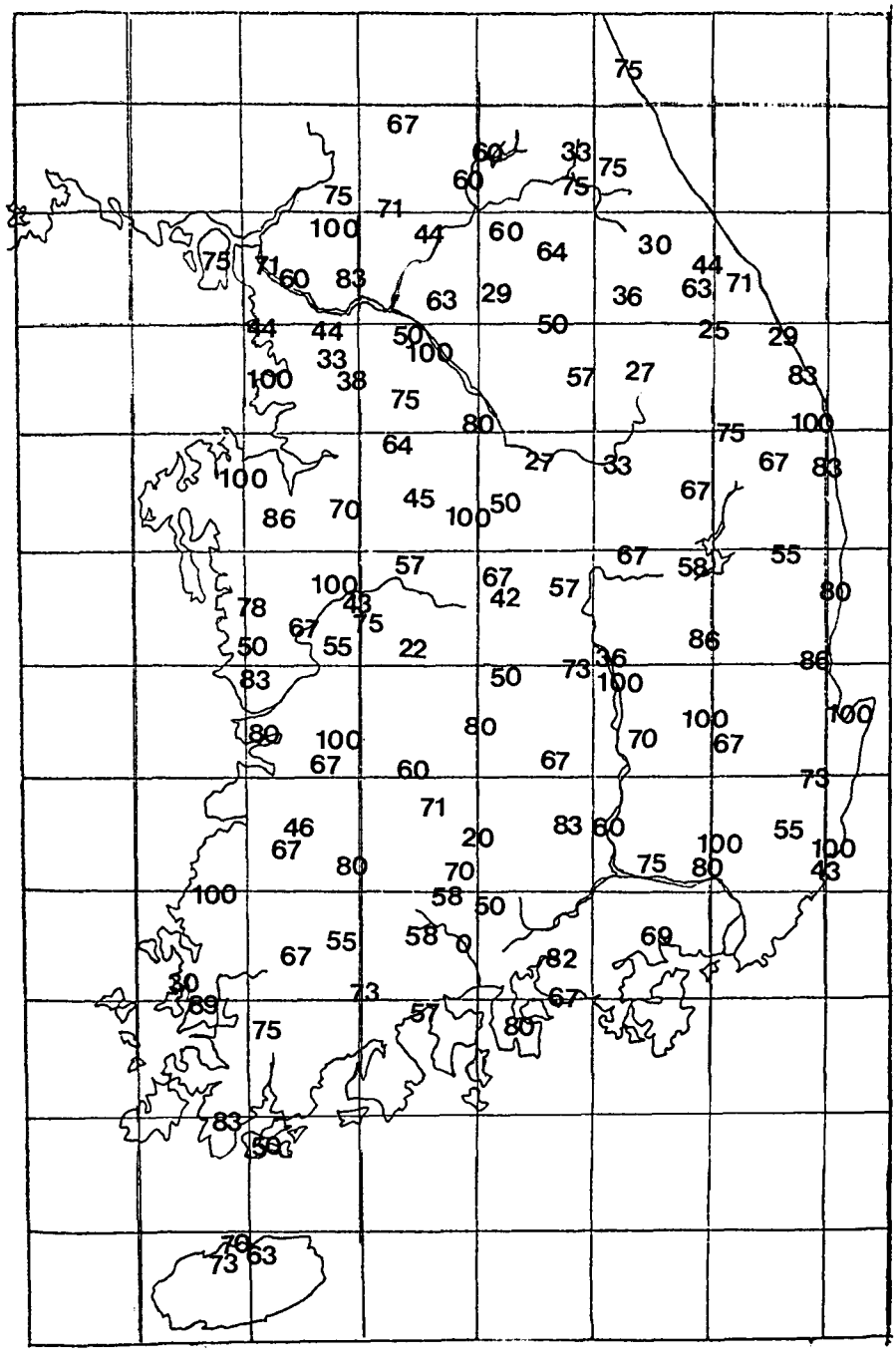


**Fig. 2.** Flora percent of $C_4$ monocotyledons in Korea.

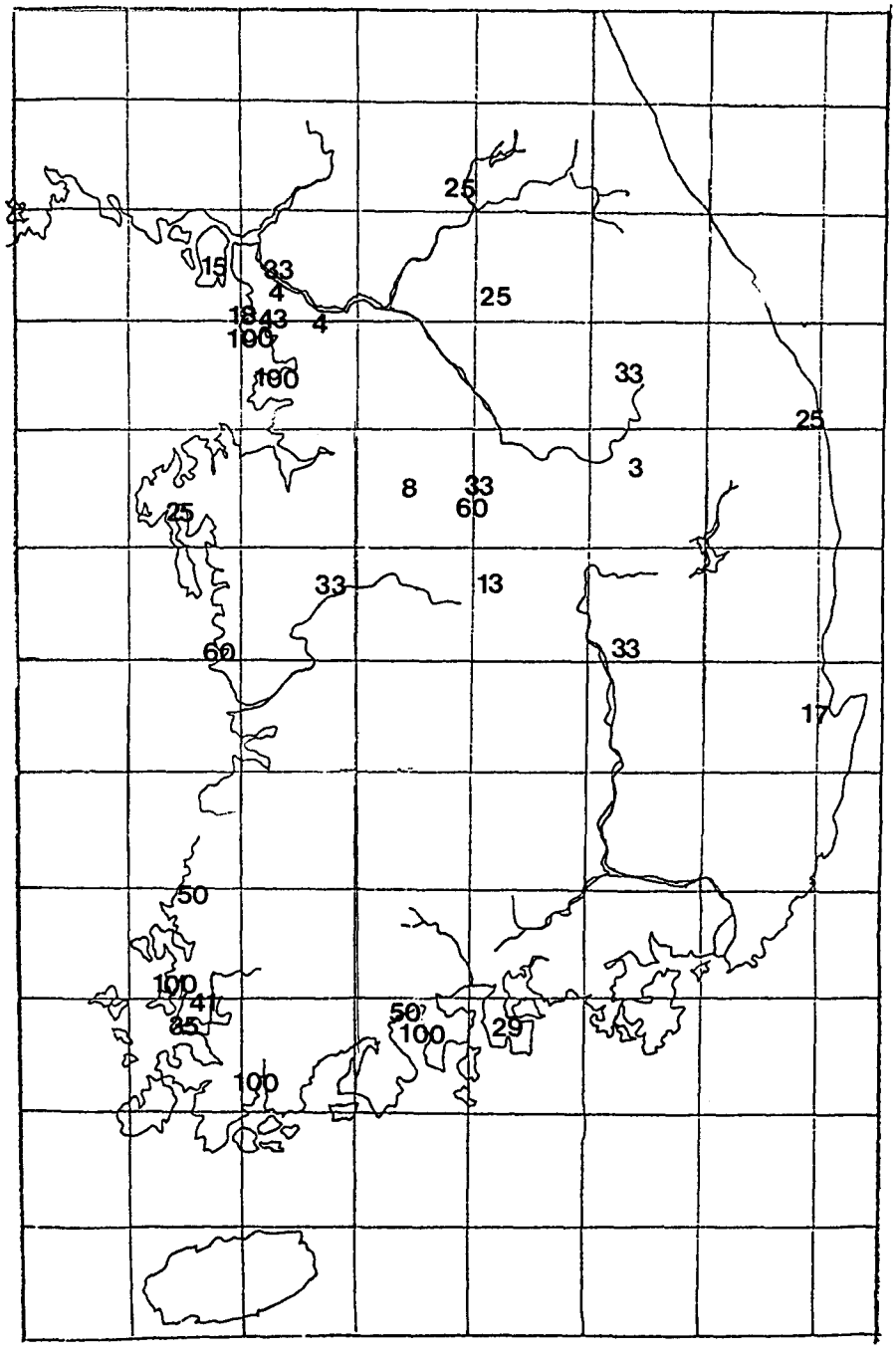


**Fig. 3.** Flora percent of $C_4$ dicotyledons in Korea.

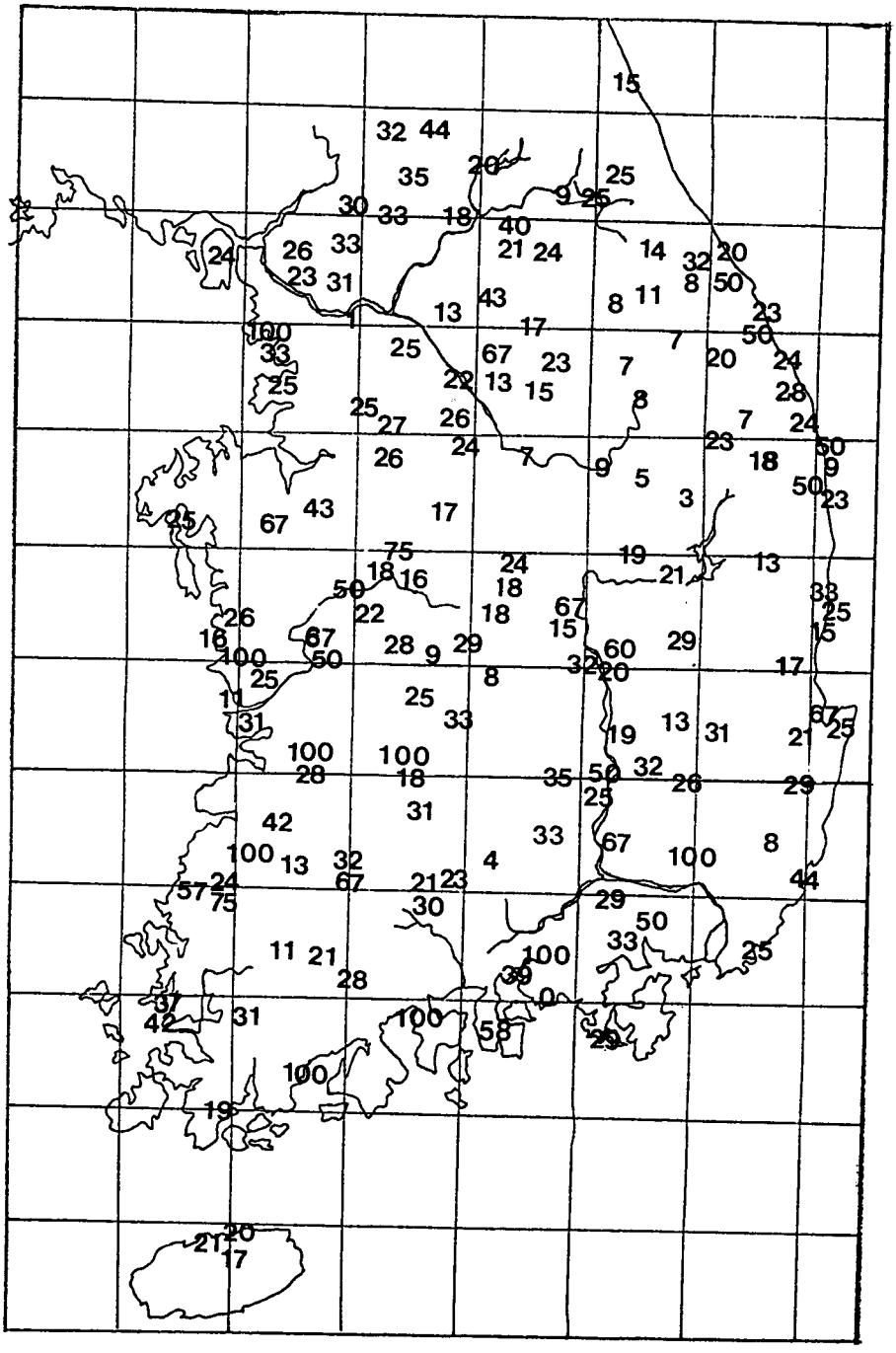

**Fig. 4.** Distribution of $C_4$ plants in Korea. The proportion of $C_4$ type plants was high in arid areas and low in humid habitats.

Seven families and 92 species of $C_4$ type plants were contained among the herbaceous plants naturally growing in Korea(Table 1.). This finding accords to the previous study by Lee.(1982) Most of $C_4$ type plants recorded were Gramineae of monocotyledons, and others were dicotyledonous weeds in cultivating area, tidal halophytes, and horticultural plants. The distributions of these $C_4$ type plants are seemed to have close relationships with the habitats. The forest destroyed by man interference, cultivating areas, and seashore areas are characterized by the dominance of $C_4$ type plants. The arid areas showed high proportions of $C_4$ type flora, while well-developed woody forests or the vegetation of humid areas were in lower proportion(Fig. 2,3,4). *Zoysia japonica* was the dominant species in six region of the 258 sites considered.

## SUMMARY

The distribution patterns of $C_3$, $C_4$ and CAM type grasses in Korea were studied. Samples were collected from 258 sites and identified and classified into $C_3$, $C_4$ and CAM type plants with several methods. The dominant grasses were determined considering the importance values.

In this study, 92 species of 7 families of $C_4$ type plants were recorded and most of them were Gramineae of monocotyledonous plant. And there existed a strong relationship the distribution of $C_3$ and $C_4$ type grasses and the habitat of these grasses. $C_4$ type grasses and facultative CAM herbaceous species were usually dominant in the arid areas, while the abundance of $C_3$ plants showed closely related with the humid areas.

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**Table 1.** List of $C_4$ plants in Korea.

| Family | Species | Korean Common Name |
|---|---|---|
| POACEAE | *Agrostis clavata* | 산겨이삭 |
| | *A. clavata* var. *nukabo* | 겨이삭 |
| | *A. alba* | 흰겨이삭 |
| | *Andropogon brevifolious* | 쇠풀 |
| | *A. ischaemum* | 바랭이새 |
| | *Arundinella hirta* | 새 |
| | *A. hirta* var. *cillare* | 털 새 |
| | *Arthraxon hispius* | 조개풀 |
| | *A. hisoidus* var. *centasiaticus* | 털조개풀 |
| | *A. hispidus* var. *typicus* | 민조개풀 |
| | *Bothriochloa parviflora* | 나도기름새 |
| | *Chloris virgata* | 나도바랭이 |
| | *Cymbopogon tortilis* | 개솔새 |
| | *Cynodon dactylon* | 우산잔디 |
| | *Coix lachryma-jobi* | 염 주 |
| | *C. lachryma-jobi* var. *mayue* | 율 무 |
| | *Digitaria sabguinalis* | 바랭이 |
| | *D. vioascens* | 민바랭이 |
| | *D. chinensis* | 좀바랭이 |
| | *Dimeria ornithopoda* | 잔디바랭이 |
| | *Eleuine indica* | 와바랭이 |
| | *E. corocana* | 아프리칸미렛 |
| | *Echinochloa macrocorvi* | 돌 피 |
| | *E. crus-galli* var. *frumentacea* | 피 |
| | *E. hispiedula* | 강 피 |
| | *E. echinata* | 물 피 |
| | *Eragrostis poaeoides* | 좀새그령 |
| | *E. cilianensis* | 참새그령 |
| | *E. Curvula* | Weeping lovergrass |
| | *E. ferruginea* | 그 령 |
| | *E. japonica* | 각시그령 |
| | *E. pilos* | 큰비노리 |
| | *E. multicaulis* | 비노리 |
| | *Eularia speciosa* | 개억새 |
| | *Imperata cylundrica* | 띠 |
| | *I. cylindrica* var. *genuina* | 들 띠 |
| | *Miscanthus sinensis* | 억 새 |
| | *M. robustus* | 큰억새 |
| | *M. sacchariflorum* | 물억새 |

Continued from Table 1.

| Family | Species | Korean Common Name |
|---|---|---|
| | *M. oligostachyus* | 억새아재비 |
| | *Muhlenbergia japonica* | 쥐꼬리새 |
| | *Oplismenus undulatifolius* | 주름조개풀 |
| | *Paspalum thunbergii* | 참새피 |
| | *Pennisetum alipecuroides* | 수크령 |
| | *Panicum bisulcatum* | 개기장 |
| | *P. miliaceum* | 기 장 |
| | *P. dichtomiflorum* | 미국개기장 |
| | *Setaria chondrachne* | 조아재비 |
| | *S. italica* | 조 |
| | *S. viridis* | 강아지풀 |
| | *S. viridis* var. *purpurascens* | 자주강아지풀 |
| | *S. gigantea* | 가라지조 |
| | *S. virid's* var. *pachystachys* | 갯강아지풀 |
| | *S. glauca* | 금강아지풀 |
| | *Sorghum nitidum* var. *majus* | 수수새 |
| | *S. bicolor* | 수 수 |
| | *S. sudanense* | 수단그라스 |
| | *Spodipogon cotulifer* | 기름새 |
| | *S. sibircus* | 큰기름새 |
| | *Sporobolus elongatus* | 쥐꼬리새풀 |
| | *S. japonicus* | 나도잔디 |
| | *Themada japonica* | 솔 새 |
| | *Zea mays* | 옥수수 |
| | *zoysis japonica* | 잔 디 |
| | *Z. tenuifolia* | 금잔디 |
| | *Z. sinica* | 갯잔디 |
| | *Z. macrostachya* | 왕잔디 |
| CYPERACEAE | *Cyperus polystachyos* | 갯방동사니 |
| 사초과 | *C. rotundus* | 향부자 |
| AMARANTASEAE | *Amaranthus blium* | 개비름 |
| 비름과 | *A. caudatus* | 줄맨드라미 |
| | *A. retroflexus* | 털비름 |
| | *A. spinosus* | 가시비름 |
| | *A. tricolor* | 색비름 |
| | *A, viridis* | 청비름 |
| | *A. mangostanus* | 비 름 |
| | *Gomphrena globosa* | 천일홍 |
| EUPHORBIACEAE | *Euphoria maculata* | 큰땅빈대 |
| 대 곡 파 | *E. supina* | 애기땅빈대 |
| | *E. humifusa* | 땅빈대 |
| CHENOPODIACEAE | *Artoplex subcordata* | 갯는장이 |
| 명아주과 | *A. gmelini* | 가는 갯는장이 |
| | *Kochia scoparia* | 댑싸리 |
| | *K. scoparia* var. *littorea* | 갯댑사리 |

Continued from Table 1.

| Family | Species | Korean Common Name |
|---|---|---|
| | *Suaeda asparagoides* | 나문재 |
| | *S. joponica* | 칠면초 |
| | *Salicornia herbacea* | 퉁퉁마디 |
| | *Salsola collina* | 솔장다리 |
| | *S. komarovi* | 수송나물 |
| PORTULACEAE | *Portulaca grandiflora* | 채송화 |
| 쇠비름과 | *P. oleracea* | 쇠비름 |
| CRASSULACEAE | *Orstachys japnnicus* | 바위솔 |
| 돌나물과 | *Sedum kamtschaticum* | 기린초 |
| | *Tribulus terrestris* | 남가새 |
| ZYGOPHYLLACEAE | | |
| 남가새과 | | |