An innovative method for the biological control of *Alternanthera philoxeroides*

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Biological invasion has become a serious global environmental problems and been considered as an important component of global change[1-2]. Invasions by alien species can have an impact at several levels of ecological complexity from genes to ecosystems[3-4]. Invasive alien species had seriously threated the biodiversity and natural ecosystems in China[5], and caused economic losses by more than US$7 billion every year[6]. *Alternanthera philoxeroides*, commonly known as Alligator weed, is an invasive amphibious plant[7]. The effect of physical methods such as mechanical or artificial salvage, removal of *A. philoxeroides* were very limited. Moreover, these measure should be carried out very carefully or would easy lead to its rebound[8]. The mainly biological control methods of *A.philoxeroides* is the introduction of natural enemies including *Arcola malloi* and *Amynothrips andersoni* [9]. However, the introduction of natural enemies had little control effect on *A. philoxeroides* especially in terrestrial conditions, where the stems of *A. philoxeroides* lignified[9-12]. Here we found that *Humulus Scandens (H. japonicus)* can better inhibit the invasion of *A. philoxeroides* by means of interspecific competition which could be an ideal biological control method to control the invasion of *A. philoxeroides*.

Ecological theory predicts that closely related species with overlapping niches are unlikely to occupy the same habitat because one species will competitively exclude the other[13-15]. Most of the existing researches on interspecific competition were focused on the competition between invasive and native plant species. Invasive species are often thought to be better competitors than native species[16-21]. However, few attention was paied on the interspecific competition between different invasive species. In fact, the physiological and ecological characteristics of different invasive plants species are different. Furthermore, most of replacement series experiments were carried out indoor but not in field conditions[22]. Here we observed some physiological indicators of two

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invasive alien plants which grew together in the same field conditions.

The result showed that the Leaf biomass, Stem biomass and root biomass of *A. philoxeroides* in CE was lower very significantly than that in CK_A respectively (n=3, P<0.001) (Fig 1). The Leaf weight of *H. japonicus* were significantly lower than that in CK_H (n=3, P<0.001), the biomass of stem and root of *H. japonicus* in CE was also lower than that in CK_H but no significant difference was found. The total biomass of *A. philoxeroides* in CK_A was higher significantly than that of *H. japonicus* in CK_H (n=3, P<0.05), but the total biomass of *A. philoxeroides* in CE was lower than that of *H. japonicus* in CE with no significant difference. Number of lateral bud and of Root length *H. japonicus* in CK_H were significantly higher than that in CE (n=3, P<0.05). N *A. philoxeroides* in CK_A is higher than that in CE. Root length of *A. philoxeroides* in CE were significantly higher than that in CK_A (n=3, P<0.05), but the number of lateral bud was lower with no significant difference than that in CK_A. Root shoot ratio of *H. japonicus* and *A. philoxeroides* in CK_H and CK_A were higher than that in CE respectively (n=3, P<0.05). The total relative yield (RYT)[23] of *H. japonicus* to *A. philoxeroides* was 0.444 and competitive rate (CR)[24] was 9.834. Therefore, the results showed that *H. japonicus* was more competitive, and inhibited strongly the growth of *A. philoxeroides.*

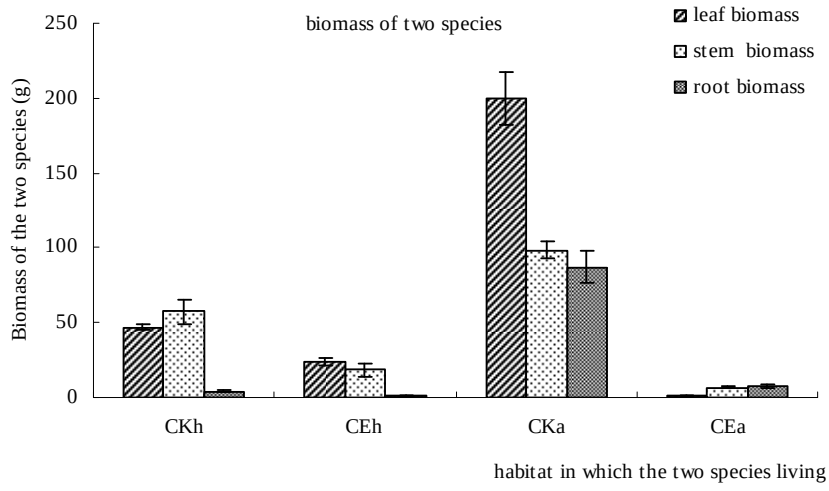

Fig 1 The leaf, stem and rood biomass of *H. japonicus* and *A. philoxeroides* in different habitats. CK_H and CK_A represent the habitats in which *H. japonicus* or *A. philoxeroides* lived alone, CE represents the habitats in which *H. japonicus* mixed with *A. philoxeroides.*

Research on biological invasions has largely focused on the impacts of introduced species

and on methods of their control[25]. Biological control of exotic weeds aims to mitigate the negative impact of invasive weeds on biodiversity, human welfare, and economy. Classical biological control can be a highly effective and cost-effcient approach to control invasive weeds. Myers and Bazely[26] listed some 40 invasive weed species that are considered to be under control at least at a regional level due to the release of biological control agents.The use of herbicide could well control aquatic A. philoxeroides but the effect was not very ideal to errestrial A. philoxeroides [27].

This study showed that *H. japonicus* can better inhibit the invasion of *A. philoxeroides* by means of interspecific competition. Furthermore *H. japonicus* is an annual herb which can be swept away by harvesting when the seeds immature in autumn. Therefore, to sow *H. japonicus* mixed with *A. philoxeroides* would be an innovative biological control method for *A. philoxeroides* which is an invasive alien plant.

METHODS SUMMARY

The study was carried out in three habitats in Ji'an city in Chain: where *H. japonicus* and *A. philoxeroides* lived alone (CK_H and CK_A), and where *H. japonicus* mixed with *A. philoxeroides* (CE). *H. japonicus* and *A. philoxeroides* were sampled form three 1.0×1.0 m^2 quadrats in each habitat. Leaves, roots and stems of all samples were separated and dried at 75 ℃ in the oven.

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Author contributions

Y.S.C. designed the field experiment. Y.S.C and Y.Z. get samples from outside. H.M.W, S.L.F. and Z.A.L. provide guidance and practical help in experimental design. All authors discussed the results and commented on the manuscript. S.L.F. supervised the project.