

The Evolution of Weed Population in Golf Turf of Southern China

Xue Guang^{1,3,*}, Ma Jianxia^{2,3}, Du Jinrong³, Li Chunyan³

¹Plant Protection Institute, Jiangsu Academy of Agricultural Science, Nanjing, China

²Institute of Botany, Jiangsu Province and Chinese Academy of Science, Nanjing, China

³East China Weed Technology Institute, Nanjing, China

Email address:

xuegnj@sina.com (Xue Guang), jenny.ma@basf.com (Ma Jianxia), eastchinaweed@sina.com (Du Jinrong)

*Corresponding author

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Abstract: Based on the investigation of weed in warm season turf of 46 Golf courses in southern China during 1998-2000 and 2013-2015 respectively. 159 kinds of weed were determined. Most of weed population or community contained 20 kinds of element weed including *Digitaria sanguinalis*, *Paspalum conjugatum*, *Axonopus compressus*, *Panicum repens*, *Poa annua*, *Cyperus rotundus*, *Kyllinga brevifolia*; *Hydrocotyle sibthorpioides*, *Oxalis corniculata*, *Kummerowia striata*, *Alternanthera philoxeroides*, *Desmodium triflorum*, *Mimosa pudica*, *Centella asiatica*, *Securinega suffruticosa*, *Viola japonica*, *Hedyotis corymbosa*, *Euphorbia humifusa*, *Lobelia chinensis* and *Alysicarpus vaginalis* in 2000. While it changed to new 20 kinds of element weed including *Digitaria ischaemum*, *Digitaria sanguinalis*, *Poa annua*, *Brachiaria villosa*, *Axonopus compressus*, *Cynodon dactylon*, *Paspalum distichum*, *Eragrostis pilosa*, *Panicum repens*, *Dactyloctenium aegyptium*; *Kyllinga brevifolia*, *Cyperus rotundus*; *Euphorbia humifusa*, *Hedyotis corymbosa*, *Desmodium triflorum*, *Hydrocotyle sibthorpioides*, *Centella asiatica*, *Alysicarpus vaginalis*, *Kummerowia striata* and *Trifolium repens* in 2015. The investigation showed that grasses were increasing rapidly, broadleaf weeds were decreasing comparing with the weeds 15 years ago in the same golf courses. The paper showed 24 pieces of picture related those population or community. Author also analyzed the possible factors to influence the evolution of weed population. It may due to hand weeding, competition, climate changing, improper maintain and improper herbicide application.

Keywords: Weed, Population, Evolution, Golf, Turf

1. Introduction

Since the first golf course named “Chung Shan Hot Spring Golf Club” set up at Guangdong province of China in 1984, the 120 golf clubs build up by the end of 1998 [1]. David C. B. (1994) pointed out that golf and turf environments is one of the four sectors to impact nation’s economy by weed [2]. A lot of paper introduced weed control in turf, but a few covered it in golf turf [3~12]. To control weed must know weed and it’s changing. Xue G. and Ma J. X. explicated that 159 weeds including 39 grasses species 15 sedge species and 105 broadleaved species were determined in the golf turf of southern China in 1998-2000. Most weed community was set up with 20 kinds of main trouble weed species included 5

grasses species, 2 sedge species and 13 broad-leaved species [13]. What is the changing of weed species and population after the turf use for golfer continuously 15 years? Why does the evolution of weed population occur? This study carried out a new survey in the same golf turf during 2013-2015. The study was to determine the weed population changing in golf turf of southern China 15 years later and to analyze the possible factors to influence the evolution of weed populations.

2. Materials and Methods

The investigation plots were located between North latitude 17.31°~32.52° and east longitude 109.42~122.11°

covering 46 golf courses included 10 clubs in Hainan province, 17 clubs in Guangdong province, 6 clubs in Fujian province, 13 clubs in Shanghai, Zhejiang, Jiangsu and An' hui province in 1998-2000 and 2013-2015 respectively. Except 6 golf clubs planted *Zoysia* and 4 golf clubs planted *Paspalum* Seashore, the rest planted Bermudagrass. Most of the golf club had set up for 6-7 years, a few had set up for 8-9 years and one had set up for 10 years. The estimating of weed damage to turf was refer to Tang's "Standard for rating level of weed by visualization" (1991) [14a]. Three types of weed were ranged, which included main trouble weed, trouble weed and potential trouble weed. Each weed species judged by the relative height (RH), relative coverage (RC), relative density (RD) and relative frequency (RF). Visualization was carried out at 3-5 fairways and 6-7 rough areas in each golf plots, where there were typical weed species in the spring and summer once in 27 golf courses and twice in 19 golf courses in one year respectively.

3. Results and Discussion

3.1. The 20 Kinds of Main Trouble Weed in 2000 and 2015

According the result of investigation, most of weed population and community was set up by the weed frequently occurred. In the year of 2000, the 20 kinds main trouble weed were *Digitaria sanguinalis*, *Paspalum conjugatum*, *Axonopus compressus*, *Panicum repens*, *Poa annua*; *Cyperus rotundus*, *Kyllinga brevifolia*; *Hydrocotyle sibthorpioides*, *Oxalis corniculata*, *Kummerowia striata*, *Alternanthera philoxeroides*, *Desmodium triflorum*, *Mimosa pudica*, *Centella asiatica*, *Securinega suffruticosa*, *Viola japonica*, *Hedyotis corymbosa*, *Euphorbia humifusa*, *Lobelia chinensis* and *Alysicarpus vaginalis*. While 15 years later, it changed to new 20 kinds of main trouble weed which were *Digitaria ischaemum*, *Digitaria sanguinalis*, *Poa annua*, *Brachiaria villosa*, *Axonopus compressus*, *Cynodon dactylon*, *Paspalum distichum*, *Eragrostis pilosa*, *Panicum repens*, *Dactyloctenium aegyptium*; *Kyllinga brevifolia*, *Cyperus rotundus*; *Euphorbia humifusa*, *Hedyotis corymbosa*, *Desmodium triflorum*, *Hydrocotyle sibthorpioides*, *Centella asiatica*, *Alysicarpus vaginalis*, *Kummerowia striata* and *Trifolium repens*.

3.2. The Changing of Weeds Species Population 15 Years Later

Investigation showed that there were always some of main trouble weeds which were as each element weed to compose population or community. These elements weed was changing according to the environment altering slowly and gradually. Comparing the population structure, the 20 kinds of weed were 5 kinds of grasses 2 kinds of sedges and 13 kinds of broadleaf weeds in the year of 1998-2000. Which has changed to 10 kinds of grasses, 2 kinds of sedges and 8 kinds of broadleaf weed in the year of 2013-2015. Obviously, the grasses were increasing rapidly but the broadleaf weeds were decreasing gradually. In grasses weed, except *Paspalum conjugatum* seceded, the rest 4 kinds of grass were still

remained. The new 6 kinds of grass included *Digitaria ischaemum*, *Brachiaria villosa*, *Cynodon dactylon*, *Eremochloa ophiuroides*, *Dactyloctenium aegyptium* and *Paspalum distichum* was added. Though sedges were only two species, survey carefully showed that *Kyllinga brevifolia* was more serious than *Cyperus rotundus* in most golf courses 15 years later. Among broadleaf weeds, 6 kinds of weed included *Oxalis corniculata*, *Alternanthera philoxeroides*, *Mimosa pudica*, *Viola japonica*, *Securinega suffruticosa* and *Lobelia chinensis* were seceded. The rest 7 kinds of weed were still remained. *Trifolium repens* was added. The result of investigation showed that *Digitaria ischaemum*, *Brachiaria villosa*, *Panicum repens*, *Kyllinga brevifolia*, *Cyperus rotundus* and *Hydrocotyle sibthorpioides* was occurred in almost every golf courses of Hainan, Guangdong and Fujian province. *Poa annua* and *Digitaria* was occurred in almost each golf courses of Shanghai, Zhejiang, Jiangsu and An' hui province. Another sign in early building courses showed that there were two type of weeds maybe trouble to everyone rapidly. One is herbicide resistant weed, another is the special weed transformed from cultivated turf such as Bermudagrass in Seashore *paspalum/Zoysia*, Seashore *paspalum* in Bermudagrass, Bentegrass in Kentucky bluegrass and *Zoysia* in Bermudagrass [15, 16]. The Picture of some main trouble weed is attached (Figure 1~24).



Figure 1. *Digitaria sanguinalis* population.



Figure 2. *Digitaria ischaemum* population.



Figure 3. Brachiaria villosa population.



Figure 8. Bermudagrass population in Paspalum seashore.



Figure 4. Paspalum distichum population.



Figure 9. Paspalum conjugatum population.

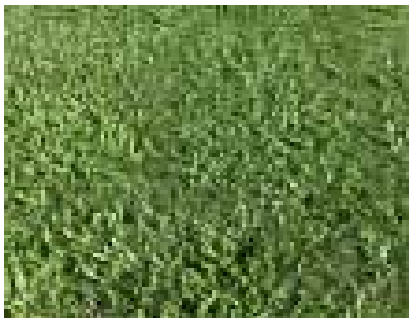


Figure 5. Axonopus compressus population.

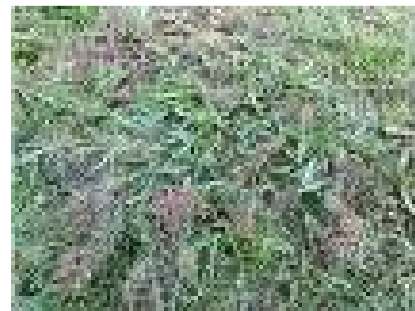


Figure 10. Eragrosis pilosa population.

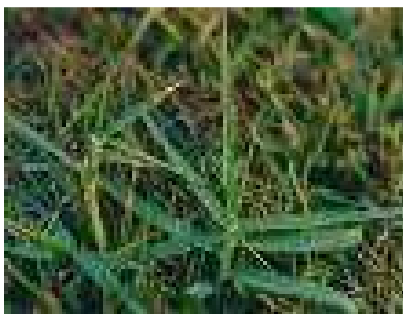


Figure 6. Panicum repens population.



Figure 11. Cyperus rotundus population.



Figure 7. Poa annua population.

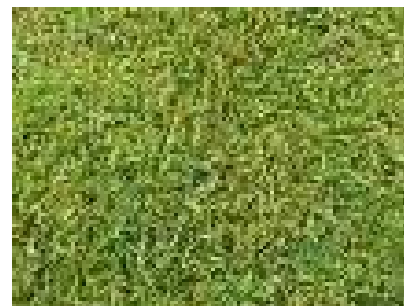


Figure 12. Kyllinga brevifolia population.



Figure 13. Cyperus & Kyllinga community.



Figure 18. Euphorbia humifusa population.



Figure 14. Hydrocotyle sibthorpioides population.



Figure 19. Euphorbia & Brachiaria community.



Figure 15. Hydrocotyle var. batrachium population.



Figure 20. Brachiaria Digitaria & Desmodium community.



Figure 16. Digitaria & Cyperus community.

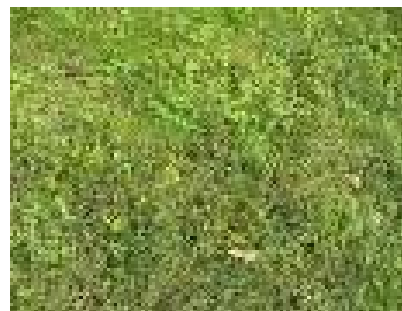


Figure 21. Poa & Oxalis community.



Figure 17. Brachiaria & Desmodium community.



Figure 22. Brachiaria, Desmodium & Kyllinga community.



Figure 23. *Desmodium* & *Panicum* community.



Figure 24. *Poa annua* & *Digitaria* community.

3.3. The Possible Factors to Influence the Changing of Weed Population

3.3.1. Hand Weeding

There was a huge weed seed bank in the sand or soil under the base part of turf. The quantity of weed seed and structure of weed species is always in changing for a long time. For the new planting turf growing healthy and strongly, more irrigation and fertilizer was needed soon after the planting. Thus a lot of weed with various species germinated from base part under the turf. Hand weeding with the help of tools usually was the main way to remove the weeds in the early period after planting (Figure 25~26). Two to three weeks later after hand weeding, annual weed which grows in the closing sand or soil layer surface maybe reduced, but number of weed seed under the base part of sand or soil layer was slowly germinating. Most erect and high stem weeds were pulled out, some creeping weeds like *Desmodium triflorum*, *Hydrocotyle sibthorpioides* and *Centella asiatica* were getting more. After annual weeds were pulled out, perennial weeds like *Cynodon dactylon*, *Paspalum distichum*, *Cyperus rotundus* and *Kyllinga brevifolia* were getting more and more soon after irrigating and fertilizing. Except for continually more hand weeding or applying herbicide. Year by year, the evolution of weed population was taken place gradually.



Figure 25. Weed population changed by hand weeding.

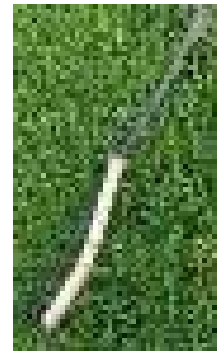
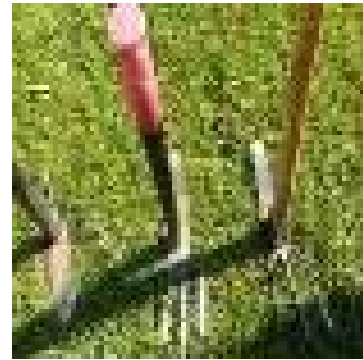


Figure 26. Some of the tools for digging weeds, which could turn over the soil, to help the weed seed of deep soil germinating.

3.3.2. Competition

Competition for light, water, nutrient and space between weed and turf is predictable response of grouping living organism into communities [17]. There were number of weed species with the form of population or community in same time and same area if the condition was suitable and resources were freely available. Sometimes, even more than 16 species of weed could grow together in one competition pool (Figure

27). *Cyperus rotundus* and *Digitaria sanguinalis* was ranked at 1st and 11th respectively among the 15 most serious weeds of world worst weeds [18]. After herbicide use in several years, the weed species would be reduced and the structure of community also would be changed (Figure 28). Prolific reproduce and production of extensive creeping rhizomes was one of the nine characteristics that affect the competitive ability of weed according to Zimdahl (1993) [19]. Both of *Cyperus rotundus* (Figure 29~31) and *Kyllinga brevifolia* (Figure 32~34) was perennial weed [20]. They created new generations not only by sexual (floral) reproduction, but also by asexual reproduction from rhizomes, tubes or bulbs. These organs are the means by which the plant spreads in all directions and it is through them that the food moves to the tubers [21]. Due to the *Cyperus rotundus* occupies the dominance over the others in utilization of light if temperature was of 35~40°C [14b]. *Cyperus rotundus* was more serious harmful than *Kyllinga brevifolia*'s, the rank of *Cyperus rotundus* in the front of *Kyllinga* in the most golf club of Hainan in 1998-2000. The result of investigation was reversal changed. With continually rainstorm causing bad drainage and frequently low mowing that altered the micro-environment. Year by year, *Kyllinga brevifolia* could stand wet and low mowing, but *Cyperus rotundus* could not afford this condition. It proved that competition ability is relative and conditionality. In dry soil and high temperature, *Cyperus rotundus* was more competitive than *Kyllinga*. While in the wet soil and low mowing, *Kyllinga* was more competitive than *Cyperus rotundus*.



Figure 29. The plant and tassel of *Cyperus rotundus*.

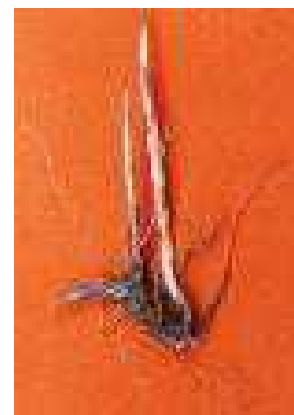


Figure 30. The rhizomes of *Cyperus rotundus*.



Figure 27. 16 kinds of weed grow in one competition pool.

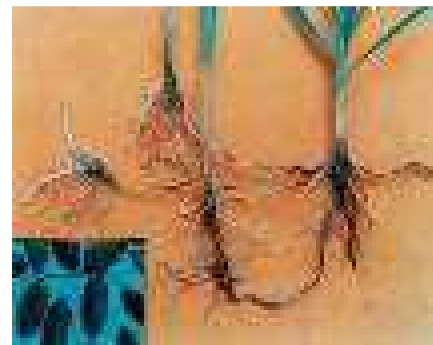


Figure 31. The tubes, bulbs and seeds of *Cyperus rotundus*.

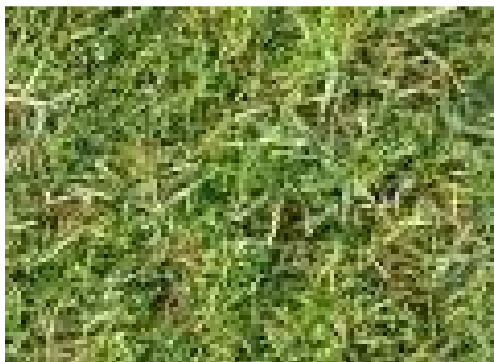


Figure 28. Competition caused weed population changed.



Figure 32. The plant & tassel of *Kyllinga*.



Figure 33. The plant & base part of Killinga.



Figure 34. The rhizomes & tassel of Killinga.

3.3.3. Climate Changing

Climate changing includes the changing of total long time characteristic weather of any region [22]. Extreme weather like high temperature and drought, typhoon and continually rain, cold snap and ice rain, snow and freezing, fog and smog occurred at random, Typhoon and continually rain converted in Guangdong, Fujian and Hainan province of southeast China every year. While along with the weather changed abnormal, it may cause some of weed prolong or reduce its life cycle. If El Nino phenomenon caused cool summer and warm winter, *Poa annua* does not get into dormant in summer. A lot of weed seed, could germinate in all season of one year in same area under proper condition in golf turf of southern China. The proper condition such as warm winter or cool summer was better for weed than cold winter or hot summer (Figure 35). Tang. H. Y. (1991) reported the proper temperature for *Poa annua* was 2~20°C to geminate. The better temperature was 6-15°C. Sometimes *Poa annua* could germinate up to 25-30°C [14c], but could not survive even it germinated if temperature continued going up before its tillering stage. While the observation in the year of 2015 found that at frequently irrigation and high level fertilizing condition, *Poa annua* could germinate and grow up over tillering stage above 32°C in the Bermudagrass of Shanghai region in 2015. The *Poa annua* plants which germinated in the fall of 2014 which still survived at over 32°C of July of 2015 in the same golf turf (Figure 36). Author also found healthy *Poa annua* which germinated in the early spring and survived in summer till to the autumn of 2015 at Hidden tiger golf course of An'hui province (Figure 37).



Figure 35. *Poa annua* in different growing stage (Jul 15, 2015, 32°C, Shanghai).



Figure 36. *Poa annua* survived in summer (Jul 15, 2015, 32°C, Shanghai).



Figure 37. *Poa annua* in summer (Jul 21, 2015, 32°C, Huangshan).

3.3.4. Improper Maintaining

Improper maintaining contained a) much fertilizing; b) fertilizing before weeding; c) improper mowing; d) frequently irrigating; e) weeding after critical period; f) frequently punching; g) frequently hand weeding; h) single weed control instead of multiple weed control. *Paspalum conjugatum*, *Mimosa pudica*, *Securinega suffruticosa* and *Viola japonica* were not adapt to low altitude mowing, so they seceded 15 years later. High mowing could help *Poa annua* escape from burning sun and survived in cool summer. High mowing is hiding weeds! A proper micro-environment for *Poa annua* survived in high mowing turf was created (Figure 38). High mowing also could help some of weeds escape from the mist of herbicide spraying or reduce herbicide rate into target (Figure 39 left). Much fertilizing also could help some of weeds grow healthy and strong in golf turf. Thus they could have strong ability to degenerate the herbicide (Figure 40).



Figure 38. In 70mm turf mowing protected *Poa* survived in hot summer on July 17, 2014.

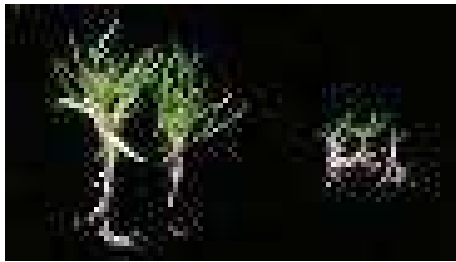


Figure 39. Left: *Poa* in rough area mowed at 45mm of Bermuda right: *Poa* in fairway mowed at 11 mm of Bermuda (48 days after herbicide application).

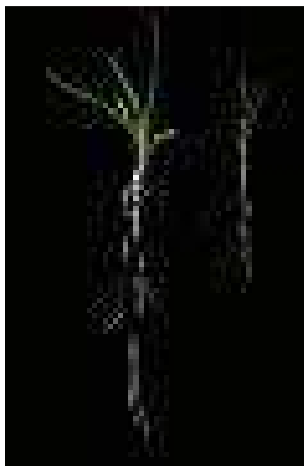


Figure 40. Left: The root of *Poa* with fertilizer right: *Poa* no fertilizer (48 days after herbicide application).

3.3.5. Improper Herbicide Application

Improper herbicide application includes a) apply after critical period; b) with wrong method; c) continually use one mode and site of action herbicide; d) at wrong rate; e) with wrong mixture; f) choice improper herbicide; g) maintenance not fit herbicide application. h) single weed control instead of multiple weed control. Any improper herbicide application mentioned above occurred, not only causes the fail of weed control, but also strongly influence weed population changing. In the golf turf ecological environment, all condition was suitable and resources were freely available for both of turf and weeds. One kind of turf faced a lot of kinds weed to compete. The need of resources for weeds may diversity to different species. In case of weed control failed, erect weed would occupy the light source first and creeping weed would

occupy the space first. While perennial weed may occupy the water and nutrient first. Time of applying fertilizer had strong effect on the weeds chemical control. When fertilizer applied before herbicide applying 4-5 weeks, the weed control would hardly get successfully (Figure 41~42). The example also showed that the excellent chemical weed control could obtain at the fairway with turf mowed at 11 mm, but failed at the rough areas mowed at 45mm (Figure 39). According to the record of turf maintenance section, broadleaved herbicide continually applied at all surveyed golf courses. Practice of weed chemical control in most golf course indicated grasses control was more difficult than broadleaf weed control. The 20 kinds of main trouble weed from the year of 2000 to the year of 2015, 5 kinds of grasses increased to 10 kinds, while 13 kinds of broadleaf weed decreased to 8 kinds. Obviously, it is a strong confident that the important factor to influence the evolution of weed population is improper herbicide application.

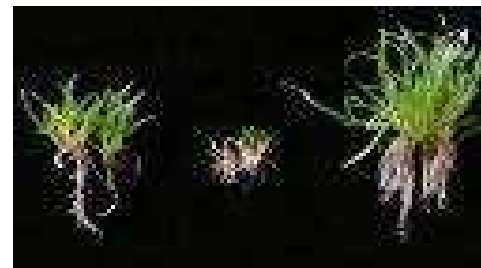


Figure 41. Left: *Poa* in bermuda, herbicide applied on Oct. 8, fertilizer on Oct 11, 2014; among: *Poa* in Bermuda, herbicide applied on Oct. 8, 2014 no fertilizer; right: *Poa annua* in the rough areas untreated (taken on Nov 27, 2014, Shanghai).



Figure 42. Left: *Poa* in the rough areas untreated; among: *Poa* in fairway mowed at 15mm herbicide applied on Oct. 8, fertilizer on Oct. 11, 2014; right: *Poa* in fairway mowed at 10 mm herbicide applied on Oct. 8, no fertilizer (taken on Nov. 27, 2014, Shanghai).

4. Conclusions

The weed population in golf turf of southern China had changed from 2000 to 2015. It showed 5 characteristics of weed and population's evolution in the past 15 years,

a) When the evolution of weed population taken place gradually in the long period, they keep stability relatively. Though the grasses increased and broadleaf weeds decreased in the 15 years, there were still 13 kinds in total 20 kinds of weed remained.

b) In the early build up golf turf, most of weeds were only

like the weeds in the original groundcover plants. With the frequently turf maintenance lasting 5-7 years, “turf-mate weed” such as *Hydrocotyle sibthorpioides*, *Centella asiatica* was getting more and more.

c) Grass weed and turf together belong to grass family (Gramineae). Even they belong to same genus. Such as *Paspalum conjugatum* (weed) and *Paspalum vaginatum* (turf). So the more broadleaf herbicide used, the more grasses weed expand. Typical grasses were *Digitaria sanguinalis* and *Poa annua*.

d) Due to perennial weed created new generations both by sexual and asexual reproduction from seeds, rhizomes, tubers or bulbs such as *Kyllinga brevifolia* and *Cyperus rotundus*. They would developed.

e) Herbicide resistant weed such as Perennial ryegrass (*Lolium perenne*), Smooth crabgrass (*Digitaria ischaemum*), and *Brachiaria villosa* should be watched out.

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