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ABSTRACT

The Lower Rio Grande Valley (LRGV) in south Texas is one of the most productive agricultural regions in southern United States. With subtropical climate and highly fertile soils, this region provides a year-round growing condition for crops. Along with citrus, major crops grown in the region are sorghum cotton and corn in the summer and vegetables in winter. Thus, a fallow period of 3-6 months between successive crops is common in the region. Growers in this region report weeds as their number one economic and agronomic problem affecting crop yield and quality and increasing the cost of production and weeds account for the largest annual loss agricultural produce. In addition to the agronomic weeds, South Texas also has invasive non-native plants which result in economic or environmental consequences. Traditionally, land managers and farmers have depended on chemical and cultural (mowing/cultivation) methods for weed management. These methods are costly, labor intensive and might potentially pose environmental problems. With additional challenges posed by herbicide resistance in weeds and changing weather patterns, weed management is an important consideration for the growers in this region. Understanding the weed ecology and biology should be part of developing and maintaining an effective weed management strategy for the LRGV. Here we present a review on the most economically and agronomically important weeds and their management options in the LRGV region.

Additional index words: Agronomically and environmentally important weeds, weed management, invasive weeds, semi-arid subtropics

Weeds, or unwanted native or non-native plants, are generally associated with any one or a set of "weedy" traits such as vegetative reproduction, self-compatibility, generalist pollination, shade tolerance, physical and chemical defense, allelopathy, etc. (Baker 1974; Schonbeck and Tillage 2011). These attributes characterize "weedy" species in their ability to outcompete other plant species through preemption and other interference mechanisms that make them highly successful, but also a major concern in crop production.

Weeds are a major problem worldwide and cause a combination of ecological, environmental, aesthetic, economic, and human health threats (Aldrich, 1984; Randall, 1997; Pimentel et al., 2005). Globally, more money is spent on weed control in agriculture than on other farm inputs and a considerable amount of research focus has been on the effective control and/or management of weeds in agroecosystems (Marshall et al., 2003). Despite the extensive chemical and mechanical weed management technologies, weeds are responsible for the largest annual loss of agricultural produce in both developed and developing countries (Liebman et al., 2016). Weed control is reported to consume over 50% of total labor needed to produce crops (Sileshi et al., 2008). Furthermore, although the advent of herbicides and other technologies such as glyphosate-resistant GM crops has provided some tools against weeds, this relief appears to be short-lived as evidenced by increasing herbicide resistance in several weeds (Mortensen et al., 2012). According to Heap (2014), 197 different weed species have evolved herbicide resistance to 14 different herbicide modes of action. Herbicides have also been associated with other negative implications to environmental and human health (Guyton et al., 2015) and with changes in climatic factors such as temperature, light intensity, humidity, and soil moisture, increased atmospheric CO_2 concentrations could lead to reduced herbicide efficacy (Ramesh et al., 2017), and unforeseen consequences. For example, prolific use of the broad-spectrum herbicide 3*,6-Dichloro-2-methoxybenzoic acid* (also known as dicamba or Dianat) has helped some farmers manage persistent broadleaf annual weeds in soybean production across the US, but has become somewhat contentious in that unexpected drift that has ultimately forced farmers to adopt resistant crops (Charles, 2016). Laboratory tests of dicamba also reveal weed resistance within only a few generations of exposure, adding to the litany of other herbicide-resistant weeds (Busi et al., 2018).

The Lower Rio Grande Valley (LRGV) in extreme southwest Texas has a subtropical climate with average annual high of 30°C and average annual low of 18.5°C and average annual rainfall is 63.5 cm. It includes USDA Plant Hardiness Zones 9b and 10a. Most of the rain falls between April and October, greater on the coast (76 cm) and decreasing toward the interior (38cm) (Foscue, 1932). Human-created habitats (agricultural fields and rangelands) are dominant in the LRGV landscape, and the vegetation here is governed by fire, soil type, and climate. Over the years, LRGV has seen a significant change in the land use and land covers. Anthropogenic and environmental factors such as population growth and extended drought period have resulted in fundamental changes in the agroecosystems, rangelands, and natural areas. Only 5% of the land area is native vegetation (Jahrsdorfer and Leslie, 1988), and a significant amount of the farmland is being transitioned to urban development (Huang and Fipps, 2006).

The LRGV region suffers from periodic droughts resulting in crop loss and giving a competitive advantage for drought tolerant weedy/invasive plants. Major weeds in the LRGV region have several characteristics that give the positive advantage over crops such as adaptation/tolerance to a wide range of environmental conditions, faster development rates, sexual as well as vegetative reproduction, high number of seed production, long seed dormancy etc. Some native plants (like common sunflower, silverleaf nightshade, pigweed, and false ragweed), have become increasingly troublesome in the agricultural fields causing a significant reduction in yield. Exotic aquatic plants (like water hyacinth, and hydrilla) and grasses (like Johnson grass, Guineagrass, buffelgrass) introduced as ornamental or forage species, have significantly altered the biological landscape, reduced forage quality, diversity of native herbaceous plants, and potentially soil characteristics. *Arundo donax* is an invader of riparian habitats, including drainage ditches and irrigation canals throughout the LRGV and its river basin in Texas and Mexico. *Arundo donax* has historically dominated these habitats where it competes for scarce water resources, reduces riparian biodiversity. Giant reed also facilitates the invasion of cattle fever ticks from Mexico into Texas and impedes law enforcement activities along the international border (Seawright et al. 2010, Esteve-Gassent et al. 2014). Several biological control agents have been released in the LRGV and are having significant impacts Goolsby and Moran 2019).

Of the several native and non-native plant species that invade agricultural fields and rangelands, there are 14 major pant species that pose serious threats (Table 1). Of these weed species, 5 are native herbaceous weeds, 5 exotic grasses, 2 exotic shrub/trees, and 2 exotic aquatic plants. Most of these weeds/invasive plants are deep rooted, drought tolerant, and have the capacity to withstand heavy grazing which them more competitive than the native plants. Forage grass species like buffelgrass and Guineagrass, with their ability to tolerate drought and disturbance, have rapidly invaded rangelands as well as roadsides in urban landscapes. These plants not only cause an economic loss in agricultural fields, but also alter the fire regime, pose a serious threat to biodiversity, soil health, and freshwater bodies, influencing the overall ecosystem function.

Mechanical and chemical treatment are the most frequent methods adopted for weed management. Mechanical weed management is generally effective in weed management, but it is expensive, labor intensive, consumes high amount of energy and most importantly results in major soil erosion problems (Montgomery, 2007). Similarly, chemical herbicides, which are the most cost-effective method of weed management in conventional farming systems and natural areas, also have serious health and environmental consequences.

CONCLUSION

Effectiveness of any weed management technique is dependent on environmental factors. In addition, environmental changes also have the potential to cause range expansion, alteration of lifecycles, and population dynamics of weeds (Ziska et al., 2011; Ramesh et al., 2017). Thus, effective weed management is critical in maintaining productivity in agricultural fields as well as biodiversity in natural areas. Growers and land managers have tried integrating multiple methods for weed management including chemical, mechanical, and biological control methods. But, with increasing challenges resulting from changes in environmental conditions, range expansion and introduction of new weed species, and herbicide resistance there is a need to understand the broader ecological context of these weeds and use a wider range of management techniques. In the ongoing battle to control weeds in the LRGV, integrated weed management techniques using many little hammers along with the modern technology are likely more effective than relying on one or two large ones.

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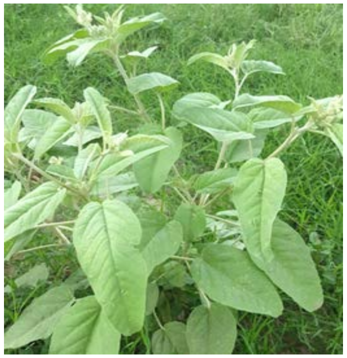
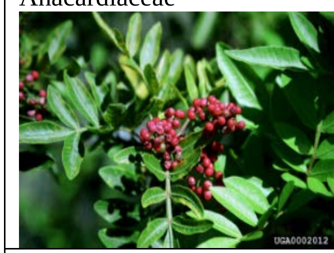
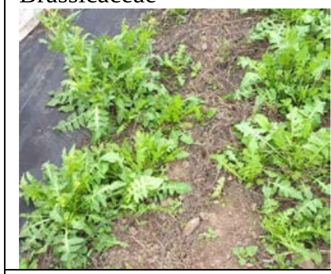
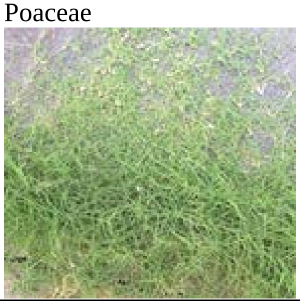
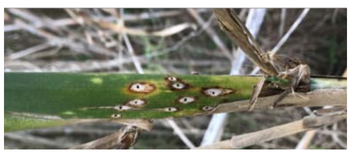
Table 1. Weeds of agronomic and environmental value in south Texas

Weed Species	**Life History and Description**	**Economic/Agronomic Impact**	**Control Options**
Broad leaves			
Common Sunflower *Helianthus annuus* Asteraceae 	Native annual weed which can grow up to 2.5 meters tall. Plants are highly branched with terminal flowers. Stems have prickly hairs. Leaves are mostly alternate and covered in coarse rough hairs. Grows in different soil types and moisture conditions. Heavy infestations normally found along roadsides, creek banks, dry prairies, and field edges.	Major pest in corn and soybean fields competing strongly for water, nutrients, and light. The forage value for livestock is poor but provides excellent feed for birds. Has evolved traits that make it aggressive and difficult to manage such as herbicide resistance to the most commonly used herbicides (Massinga et al., 2005), high degrees of resistance to herbivory (Pilson and Decker 2002), and allelopathy (Leather 1983; Alsaadawi et al. 2012).	Cultivation and herbicide treatment are generally used for sunflower management. However, it has been reported that common sunflower has evolved herbicide resistance.
False Ragweed, whitetop weed *Parhtenium hysterophorus* L. Asteraceae 	Native annual prolific weed, which can grow up to 150 cm in height. Plants flower when they are 4-8weeks and may flower for several months and an individual plan is reported to produce 15,000-25000 seeds annually (Kaur, 2014), and these seeds are known to remain viable for several years with seed viability 80% or higher (Navie et al., 1998). Heavy infestation generally found in the edges of fields and is reported to prefer dry soils.	Noxious weed in America, Asia, Africa and Australia. Can cause allergic respiratory problems, contact dermatitis, mutagenicity in human and livestock. Drastic crop yield reduction because of allelopathy.	Mechanical, chemical and biological control strategies have not been individually successful in controlling the proliferation of *P. hysterophorus*.

Silverleaf nightshade, *Solanum elaeagnifolum* A. Cavanilles Solanaceae 	Native perennial plant that grows 10cm-90 cm in height. Has extensive root system that can extend up to 3 m deep. It gets its name from the short, white or silvery pubescence in the leaves and stems. Reproduces by creeping rhizomes, roots and by seeds. Single plant can produce 200 berries per growing season with thousands of seeds (CABI, 2018). Under favorable conditions, silverleaf nightshade is reported to have typically high seed longevity, viability, and germination rates. Adapted to wide range of habitats, thrives in dry disturbed lands.	Serious weed of prairies, open woods, and disturbed soils in Texas where it is native, a noxious weed in 21 US states, and a major invasive weed in many semiarid regions in the world. Toxic to animals, serves as an alternative host for phytophagous insects and plant diseases, and has allelopathic potential.	There is currently no single effective control mechanism for silverleaf nightshade. Since the plant can easily regenerate from roots and root fragments chemical or mechanical control are not effective. Further research is needed to develop an effective integrated management strategy incorporating herbicides with different mode of action, mechanical, and biological control for silverleaf nightshade.
Brazilian pepper *Schnius tenebrionifolia* Raddi Anacardiaceae 	An evergreen exotic invasive perennial shrub/tree that grows up to 10 m tall. Birds and mammals attracted to the red fruits are primarily responsible for seed dispersal leading to the rapid spread.	Aggressively invades variety of coastal and upland habitats in Florida, California, Hawaii, and Texas. Serves as an alternate host for the exotic diaprepes root weevil, a serious citrus pest (McCoy et al., 2003). Volatiles released by roots can cause allergic reaction and respiratory illnesses in humans (Morton, 1978)	Herbicide treatment and mechanical removal are known to be effective in Brazilian pepper management. A biological control program is underway in Florida (Wheeler et al. 2017) Permitted agents may be useful in TX.
Palmer amaranth, careless weed, *Amaranthus palmeri* S. Watson Amaranthaceae	Native, deep tap rooted summer annual that can grow up to 2 m in height. Dioecious plant capable of prolific seed production, a single female Palmer amaranth plant can produce up to 600,000 seeds. These seeds are generally transported through irrigation water, wind, and farm equipment. Grows in wide range of habitats including roadsides, natural areas, and agricultural fields.	One of the most troublesome weeds in vegetable and row crops in southern United States. Palmer amaranth has the most aggressive growth habit (more than 2inches per day) and is extremely competitive. Under favorable conditions Palmer amaranth plants are nitrogen accumulators and store high concentrations of nitrates which upon conversion to nitrate during	There is no single effective method for Palmer amaranth management, and the evolution of herbicide resistance has made this even more challenging. Thus, for long-term management integrated method including crop and herbicide rotation, cover crops, cleaning farm equipment, and removing weeds before they set seeds is important.

		digestion can be poisonous to livestock. It is also known to suppress crop growth.	
London rocket *Sisymbrium irio* C. Linnaeus, Brassicaceae 	Highly competitive winter annual weed native to Europe. It can grow up to 0.5 m tall. Young plant exists as rosettes and develop flowering stems at maturity. It reproduces only by seed in late winter or spring. Grows in roadsides, fields, orchards, vineyards, gardens, and other disturbed sites.	In the RGV, London rocket is reported to harbor curly top disease 6 months out of the year (Creamer et al., 2004).	Physical removal or cultivation before seed production, as well as herbicide treatment are reported to be effective in London rocket management.
Monocots (grasses)			
Common bermudagrass, *Cynodon dactylon* L. Poaceae 	Sod forming perennial exotic grass imported from Africa. It grows up to 0.5 m tall. It can produce high number of viable seeds and vegetative reproduction through stolons and rhizome. Adapted to grow in a wide variety of soil types but does not thrive under shade.	Is generally grown as turfgrass or as forage for livestock but also one of the most successful invasive weeds in Texas.	Deep plowing, serial cultivation and herbicides have been used for management but it difficult to manage because of its deep rhizomes and rapid reproduction rates.
Johnson grass *Sorghum halepense* L. (Pers.) Poaceae	Exotic perennial weed introduced from the Mediterranean region of Europe and Asia. Can grow more than 2m tall. Reproduces by rhizomes as well as seeds which can remain viable for up to 20 years.	It is good for grazing livestock and for erosion control. It makes fair quality hay. Listed as one of the world's 10 worst weeds (Holm et al., 1977). Major weed of corn, cotton, sugarcane and soybean in tropical to temperate climates (Warwick	Some populations are resistant to herbicide. Prevention is the best management technique. Since Johnsongrass has long rhizomes, hand-removal is difficult in larger infestations. Grazing by foraging

	Grows well in wet disturbed soils, particularly along irrigation ditches and streams, field borders and roadsides.	and Black, 1983). With competition for resources, allelopathy, and a serving host for crop pests, causes a severe loss in crop yield.	animals can maintain the population of the plant.
Arundo donax L, Giant reed, Carrizo cane Poaceae   Arundo wasp damage on *Arundo donax*.	Exotic perennial species that can grow more than 6 m in height. One of the largest herbaceous grass. Introduced from Mediterranean Spain. It produces flowers in the upper tip of the stem but sexual reproduction to the species, as well as seed viability, dormancy, germination and seedling establishment is not fully understood (CABI, 2018). Population expansion occurs almost exclusively through vegetative reproduction either from underground rhizome extension of a colony or from plant fragments (Else, 1996). It grows on a variety of soil types from loose sands and gravelly soils to heavy clays and river sediments and frequently found in or near water (Spencer et al., 2008).	It invades wetlands such as ditches, irrigation canals, riparian areas, and competes for water resources. In Texas, it facilitates cattle fever tick incursion and survival in the transboundary region between the U.S. and Mexico (Seawright et al., 2009).	A biological control program has been completed in TX, primarily along the Rio Grande. Two biocontrol agents have had significant impacts, with above ground biomass gradually decreasing and native vegetation returning. An integrated biological plus mechanical topping of the carrizo cane at 1 m has also been developed. The integrated program accelerates decline of the carrizo cane, improves within stand visibility. (Goolsby and Moran, 2009, Moran et al., 2017)
Megathrysus maximus (Jacq.) B.K.Simon & S.W.L.Jacobs, Guineagrass Poaceae	Exotic perennial grass from Africa that grows up to 1-3 m tall. Can spread from seeds and rhizomes. Has large and spreading seed heads with multiple branches. Seeds often have purple tinge. It is shade and drought tolerant and prefers fertile soils but has adapted to a wide variety of conditions in the subtropics. Two phenotypes (small and giant) occur in Texas. The small phenotype is widespread in south	Highly successful invader introduced as a forage grass. Fire resistant. Is reported to cause a decline in the population of quail and other seed feeding birds (Kuvlesky et al., 2002).	Physical and chemical, and control methods are all reported to have limited impact in rangelands. Chemical control in cropland and citrus orchards can be effective but costly. Classical biological control is being investigated (Mercadier et al., 2010).

	Texas and northeastern Mexico. The giant form is only known to occur in Brownsville, Texas on the river adjacent to Matamoros, Mexico		
Pennisetum cilare L. Buffelgrass Poaceae 	Exotic perennial weed from Africa that was originally introduced for forage and erosion control (USDA, 2017). It grows up to 1.5 m tall at maturity. Can reproduce within a span of 6 weeks multiple times a year (Hanselka, 1988). Since seeds are light, "fluffy", umbrella-like, and dispersed primarily by wind and water. Not cold tolerant. Known to colonize open, recently disturbed rangeland areas, shade tolerant, and shade may promote its growth on some sites.	A popular pastoral grass species grown widely in tropical and subtropical arid rangelands around the world. It rapidly forms dense stands displacing native plants. The plant has adapted to fire regimes and the thick stands are known to modify fire regimes. Is also reported to cause a decline in the population of quail and other seed feeding birds (Kuvlesky et al. 2002).	Physical removal, hand-pulling, grubbing, and hoeing buffelgrass are reported to be effective (Hauser, 2008).
Tamarix spp., Athel pine, Saltcedar Tamaricaceae	Exotic deciduous shrub or small trees that grow up to 9m tall and form dense thickets. Tamarix sp. produce massive number of seeds annually, but they can also reproduce vegetatively from roots, broken stems and branches (Glenn and Nagler, 2005). They normally grow in moist soils near streams, rivers, and lakes and are known to tolerate extreme salinity (Natale et al., 2010).	A large, mature plant is reported to absorb up to 757 L (200 gallons) of water a day (Holdenbach, 1987). Unfit for animal consumption because it lacks protein. Stem and leaves secrete a high concentration of salt into ground suppressing the growth of native plants. Reported to replace cottonwoods, willows, and other riparian vegetation from their native habitats (Sudbrock, 1993).	Mechanical and chemical methods have been used to manage Tamarix plants. However, because of high regenerative capability, profuse seed production, and high rates of seedling establishment none of these methods provide effective management. A biological control agent was released in Texas but only occurs in far west Texas and the Trans-Pecos (DeLoach et al., 2007).

	Saltcedar dominates the communities along the Rio Grande River in south Texas.		
Aquatic Weeds			
Eichornia crassipes (Mart.) Solms Water hyacinth *Pontederiaceae* 	Free floating perennial invasive aquatic plant Native to South America but has naturalized much of the Southern United States. Can reproduce vegetatively or by seeds which can remain viable in sediment for several years. Stems are stout and erect connected by stolons. Leaf stems are swollen and spongy. Creates dense floating mats up to 2 meters thick.	Outcompetes and displaces native plants, depletes oxygen levels in water, blocks irrigation canals and interferes with recreational activities such as boating, swimming, and fishing.	Chemical, biological, and mechanical methods have been adopted to manage water hyacinth but because of its aggressive growth rate no one single method is effective in managing water hyacinth. Thus, the best method is to prevent it from freshwater bodies and manage the nutrient concentration in the water (Soti and Volin, 2010)
Hydrilla verticiliata (L.f.) Royle Hydrilla Hydrocharitaceae 	Submerged perennial invasive aquatic plant native to Southeast Asia and Australia. Is resilient to freezing or drought. Can reproduce vegetatively or by seeds. However, vegetative reproduction is more effective. Has long branching stems that reach the water surface and form thick mats.	With its dense mats on the water surface, hydrilla lowers dissolved Oxygen in water, restricts native plant growth, hinders water flow.	No single method is effective in managing hydrilla. Mechanical methods have been used most frequently but because the plant is able to spread from a single fragment mechanical method is not effective. Biological control agents (insects) have been released in the Lower Rio Grande Valley as well as sterile carp (Grodowitz et al., 2000)