www.HRACGLOBAL.com

Integrated control and herbicide management of Palmer amaranth in South Africa

History and biology

- During March 2018 Palmer amaranth (*Amaranthus palmeri)* was positively identified for the first time in South Africa in the Douglas area (Northern Cape) and is a threat to agriculture in South Africa if not effectively eradicated.
- Palmer amaranth is an annual herbaceous plant, native to north-western Mexico, and southern California, New Mexico and Texas[1].
- The weed has been identified as an economically important weed species in maize, cotton, and soybean in the United States[2-4].
- Its rapid growth rate, capability to produce an abundance of offspring (up to 600,000 seeds per plant), genetic diversity and ability to tolerate adverse conditions are some of the characteristics that contributed to this weed species becoming such a dominant and difficult-to-control weed[5].
- Palmer amaranth is dioecious, having separate male and female plants. It is accordingly an obligate out-crosser, which allows for hybridization, and potentially greater mutation rates. Local Amaranthus species such as *Amaranthus hybridus* (common pigweed), *Amaranthus spinosus* (thorny pigweed) and *Amaranthus thunbergii* (red pigweed) are monoecious (male and female flowers on the same plant).
- Due to its dioecious nature, the weed has a remarkable capability for acquiring herbicide resistance, with resistance reported for eight mechanisms-of-action (MOAs) internationally: ALS enzyme inhibition (Group B), PSII inhibition (Group C1), PPO enzyme inhibition (Group E), HPPD enzyme inhibition (F2), EPSPS enzyme inhibition (Group G), microtubule inhibition (Group K1), inhibition of cell division (Group K3) and synthetic auxins (Group O)[6].
- Characteristics that make Palmer amaranth a competitive weed include a C4 photosynthetic mechanism, aggressive growth at higher temperatures, and high water-use efficiency[7-9].
- Palmer amaranth has demonstrated an aggressive growth rate of more than 6 cm per day (2 inches/day) under full light[8] which make timely application of herbicides a challenge.
- Seeds are small (1 to 2 mm), smooth and round or disc-shaped[10] and are pre-dominantly gravity dispersed. Seed dispersal also occur via irrigation, or other water flow as well as through agricultural management practices such as ploughing and harvesting[5]
- The long-term persistence of the seeds in the soil seedbank is currently still under debate. Seed longevity of about 3 years is reported. Less than 50% viability has been reported after one year at burial depths of up to 10 cm, but it was also found that some seed may survive for extended periods, especially at greater depths (<40 cm)[11]. It is suggested that that this seed could be a source of infestation, should it be brought back to the surface by tillage.

Identification

- Palmer amaranth is characterized as a tall (up to 2 m), erect, broadleaf weed with lateral branching.
- The leaves are hairless, alternate, and lanceolate shaped in young plants (Photo 1) and become ovate as plants mature[10].

Photo 1. Lanceolate shaped leaves, and V-shaped chevron that is visible on some but not all plants (C Reinhardt, SAHRI UP)

- The upper side of the leaves is often marked with a silver-colour, V-shaped chevron. (Photo 2)

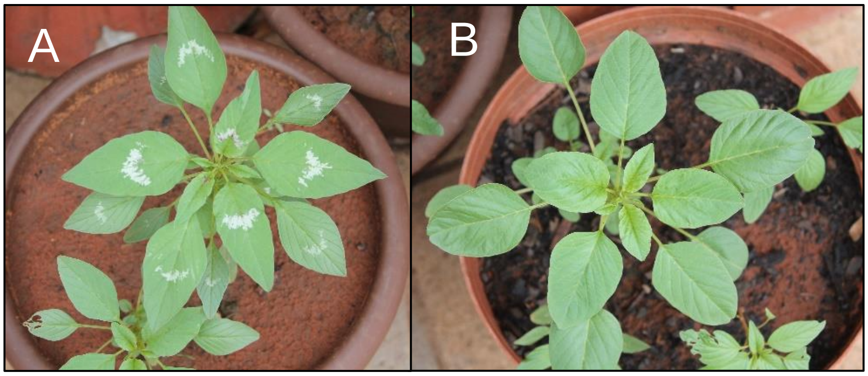

Photo 2. Palmer amaranth seedlings with and without chevron (C Reinhardt, SAHRI UP)

- Palmer amaranth's leaf petiole is often as long as, or significantly longer (up to 3 cm longer) than its leaf blade (Photo 3), whereas common pigweed has a leaf petiole with in most cases same length or shorter, and very rarely slightly longer, than its leaf blade length.

Photo 3. Palmer amaranth's leaf petiole is as long as, or longer (up to 3 cm longer) than its leaf blade (C Reinhardt, SAHRI UP)

- The flowers of Palmer amaranth cluster together to form a terminal cylindrical inflorescence. The male and female inflorescences look similar, but can be distinguished by touch: the male inflorescence is softer, whereas the female inflorescence is rougher and pricklier (Photo 4 A and B). Male inflorescences also distinguished by presence of pollen sacs and pollen which has bright yellow colour.

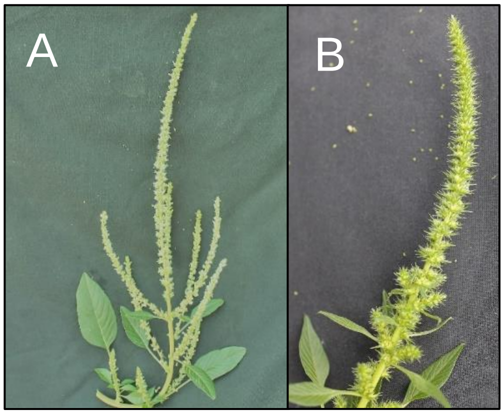

Photo 4. Male (A) and female (B) flower of Palmer amaranth (C Reinhardt, SAHRI UP)

Potential yield impact

- Palmer amaranth has a rapid growth rate and ability to accumulate large biomass quickly, which contributes to it being an extremely competitive weed. Documented yield losses caused by Palmer amaranth infestation are indicated in Table 1[5].

Table 1. Yield loss attributed to interference by Palmer amaranth when present from crop emergences

Crop	Plants per m^2	Yield loss (%)	Plants per m^2	Yield loss (%)
Cotton	0.11	11	1.10	59
Maize	0.66	11	10.50	91
Peanut	1.10	28	6.00	68
Sorghum	0.35	13	1.58	50
Soybean	0.33	17	10.50	79
Sweet potato	0.47	56	6.13	94

- Palmer amaranth plants also interfere with the harvesting process of cotton. The large amounts of biomass attained by mature Palmer amaranth plants, compromise harvest efficiency by the frequency of work stoppages needed to dislodge thick plant stems from harvest equipment[12].
- The weed, in addition, serves as a host to several nematode species; it is a moderate host to, amongst others, *Meloidogyne incognita* (Kofoid &White) Chitwood, race 3)[13] .

Management of herbicide-resistant Palmer amaranth

- As Palmer amaranth is new to South Africa, it is yet uncertain to what extent the current population will be resistant to the various MOAs most commonly utilized within our industry. Most populations in the USA are already resistant to glyphosate. Whilst several MOAs are still being tested, preliminary studies conducted by the South African Herbicide Resistance Initiative (SAHRI) on the South African population from Douglas showed the population to be 'probably' resistant (or at least highly tolerant) to glyphosate and possibly also resistant to chlorimuron and mesotrione (C. Reinhardt – personal communication). Additional research is required to verify these results. Producers should accordingly refrain from using these MOAs solely to control Palmer amaranth specifically. All new populations must be immediately reported to DAFF as well as SAHRI (Dr Reinhardt; dr.charlie.reinhardt@ gmail.com), as it is imperative that the herbicide resistance of such populations to available MOAs be established as soon as possible.
- Make sure that all Palmer amaranth plants are controlled prior to planting through tillage practices. Internationally *registered* burndown herbicides such as those of Group D (e.g. paraquat) are utilised to control the weed. Auxin-type herbicides such as 2,4D and MCPA can be utilized pre-plant where crop rotation systems allow. As this species in new to South Africa, current registered herbicides do not specifically have this species on their label. Table 2 provides a list of all registered active ingredients (herbicides) for the control of *Amaranthus* spp.

- Both pre-and post-emergence control must form part of a general weed control programme. In the US, recommendations generally emphasise the use of residual pre-emergence herbicides for the control of the weed, especially for crops with limited post emergence herbicide options, as residual herbicides will reduce the selection pressure of the few post-emergence herbicide options available. Producers are, however, warned not to rely heavily on single modes of action when applying pre-emergence herbicides, whist note must be taken on the impact that such residual herbicides may have on crop rotation programmes.
- It has similarly been found that post-emergence herbicides, applied in tank mixtures of at least two herbicides (different modes of action) gave the best control in crops such as maize. Producers should, however, always refer to product labels before tank mixing products. Due to the rapid growth rate of the weed, producers should take note that a very narrow time window is available for post-emergence herbicide control.
- Deep turning of soil, for e.g. with a mouldboard plough and in-crop cultivation are two potential solutions to reduce the germinable soil seedbank, and for controlling emerged seedlings in herbicide-resistant populations[14]. The small size of seed necessitates a shallow position within the soil profile for successful establishment. It has been demonstrated that seed germinated more frequently at <2.5 cm depths than at e.g. 5.1 cm depths[9].
- Cultivation practices that create unfavourable environmental conditions for germination and growth of the weed will be beneficial for the control of this weed. Practices that accordingly give the crop a competitive advantage, whilst also limiting sunlight reaching the soil surface, can be considered and included:
    - *Hand-weeding*: although costly, must form part of the control/eradication programme, especially from an early stage of infestation in fields when limited number of weeds are present. Palmer amaranth has prolific vegetative growth abilities (vegetative reproduction - photo 5). Weeded plants must accordingly be removed from fields and burnt in order to ensure effective control.
    - *Earlier planting dates*: Provided that soil conditions (temperature and moisture) are favourable, consideration could be given to plant crops earlier. This will allow the crop to establish sooner, thus providing a competitive advantage. The leaf canopy will also be established sooner with the shading effect being unfavourable for weed germination and growth.
    - Narrow row spacing together with optimum plant densities.
    - Cover crops not only shelter the Palmer amaranth seed from sunlight but also interfere physically with the growth of the weed. Allelopathy from cover crops can be an additional advantage for suppression of this weed.
    - Crop rotation generally allows for a greater variety of herbicides (modes-of-action) to select from. Once registered herbicides are available, crop rotation must form part of the management strategies.
- Scouting for, and the control of Palmer amaranth, before they flower and set seed around field edges and ditch banks is essential.
- Harvest infested fields last and afterwards thoroughly clean equipment to prevent spread of this weed.

Photo 5. Vegetative growth observed on weeded plants left in the field. (C Reinhardt, SAHRI UP)

Table 2. Herbicides and mode of action groups registered for *Amaranthus* spp. in South Africa[15]

Active ingredient(s)	HRAC-Group	Mode of Action	Chemical family	Registered for use on the following crops
chlorimuron-ethyl	B	Inhibition of acetolactate synthase ALS	Sulfonylurea	Soybeans, sugarcane
diclosulam	B	Inhibition of acetolactate synthase ALS	Triazolopyrimidine	Groundnuts, soybeans
flumetsulam	B	Inhibition of acetolactate synthase ALS	Triazolopyrimidine	Dry beans, green beans, groundnuts, maize, soybeans, clovers, cowpeas, lucerne, leguminous pastures
halosufuron-methyl	B	Inhibition of acetolactate synthase ALS	Sulfonylurea	Citrus, grain sorghum, maize, sugarcane, avocadoes, mangoes, tobacco, wheat
imazamox	B	Inhibition of acetolactate synthase ALS	Imidazolinone	Canola, clover, lucerne, leguminous pastures, medics, seradella (pasture)
imazamox/imazapyr	B	Inhibition of acetolactate synthase ALS	Imidazolinone	Sunflower
imazethapyr	B	Inhibition of acetolactate synthase ALS	Imidazolinone	Dry beans, groundnuts, soybean
flumetsulam/sulcotrione	B/F2	Inhibition of acetolactate synthase ALS / Inhibition of 4-HPPD	Triazolopyrimidine / Triketone	Maize
ametryn	C1	Inhibition of photosynthesis at PS II	Triazine	Bananas, Cassava, pineapples, sugarcane
amicarbazone	C1	Inhibition of photosynthesis at PS II	Triazolinone	Sugarcane
atrazine	C1	Inhibition of photosynthesis at PS II	Triazine	Grain sorghum, maize, pineapples, sugarcane, canola
atrazine/cyanizine	C1	Inhibition of photosynthesis at PS II	Triazine	Maize, sweetcorn, sugarcane
atrazine/terbuthylazine	C1	Inhibition of photosynthesis at PS II	Triazine	Grain sorghum, maize
bromacil	C1	Inhibition of photosynthesis at PS II	Triazine	Citrus, pineapples
hexazinone	C1	Inhibition of photosynthesis at PSII	Triazinone	Sugarcane
metamitron	C1	Inhibition of photosynthesis at PS II	Triazinone	Beetroot, sugar beet
metribuzin	C1	Inhibition of photosynthesis at PS II	Triazinone	Potatoes, sugarcane, tomatoes, barley, lucerne, asparagus, leguminous pastures, maize
prometryn	C1	Inhibition of photosynthesis at PS II	Triazine	Carrots, cotton, peas

Active ingredient(s)	HRAC-Group	Mode of Action	Chemical family	Registered for use on the following crops
simazine	C1	Inhibition of photosynthesis at PS II	Triazine	Apples, asparagus, canola (triazine resistant), citrus, grapes, pears, lupines
simazine/terbuthylazine	C1	Inhibition of photosynthesis at PS II	Triazine	Apples, canola (triazine resistant), citrus, grapes, pears
terbuthylazine	C1	Inhibition of photosynthesis at PS II	Triazine	Apples, citrus, grapes, maize, grain sorghum
terbutryn	C1	Inhibition of photosynthesis at PS II	Triazine	Groundnuts, peas
atrazine/sulcotrione	C1/F2	Inhibition of photosynthesis at PS II / Bleaching: inhibition of 4-HPPD	Triazine/Triketone	Maize, sugarcane, sweetcorn
atrazine/mesotrione/s-metolachlor	C1/F2/K3	Inhibition of photosynthesis at PS II / Bleaching: inhibition of 4-HPPD / Inhibition of VLCFAs	Triazine / Triketone/ Chloroacetamide	Maize
atrazine/metazachlor/terbuthylazine	C1/K3	Inhibition of photosynthesis at PS II / Inhibition of VLCFAs	Triazine / Chloroacetamide	Maize
atrazine/metolachlor	C1/K3	Inhibition of photosynthesis at PS II / Inhibition of VLCFAs	Triazine / Chloroacetamide	Maize
atrazine/metolachlor/terbuthylazine	C1/K3	Inhibition of photosynthesis at PS II / Inhibition of VLCFAs	Triazine / Chloroacetamide	Maize
atrazine/s-metolachlor	C1/K3	Inhibition of photosynthesis at PS II / Inhibition of VLCFAs	Triazine / Chloroacetamide	Grain sorghum, maize, sugarcane
atrazine/s-metolachlor/terbuthylazine	C1/K3	Inhibition of photosynthesis at PS II / Inhibition of VLCFAs	Triazine / Chloroacetamide	Maize
atrazine/bendioxide	C1/Unknown	Inhibition of photosynthesis at PS II / Unknown	Triazine / Unknown	Grain sorghum, maize
diuron	C2	Inhibition of photosynthesis at PS II	Urea	Avocadoes, bananas, coffee, macadamias, mangoes, pecans, pineapples, sugarcane, citrus
linuron	C2	Inhibition of photosynthesis at PS II	Urea	Carrots, gladioli, maize, parsley, parsnip, potatoes, sweet potatoes
fluometuron/prometryn	C2(F3)/C1	Inhibition of photosynthesis at PS II (Inhibition of carotenoid biosynthesis)	Urea / Triazine	Cotton

Active ingredient(s)	HRAC-Group	Mode of Action	Chemical family	Registered for use on the following crops
diuron/metribuzin	C2/C1	Inhibition of photosynthesis at PS II	Urea / Triazinone	Sugarcane
diuron/terbacil	C2/C1	Inhibition of photosynthesis at PS II	Urea / Uracil	Apples, pears, plums
diuron/paraquat	C2/D	Inhibition of photosynthesis at PS II / Photosystem-I-electron diversion	Urea / Bipyridilium	Sugarcane
bromoxynil	C3	Inhibition of photosynthesis at PS II	Nitrile	Barley, grain sorghum, lucerne, leguminous pastures, maize, oats, wheat
ioxynil	C3	Inhibition of photosynthesis at PS II	Nitrile	Garlic, onions
bendioxide	C3	Inhibition of photosynthesis at PS II	Thiadiazine	Barley, chillies, dry beans, grain sorghum, green beans, green peppers, groundnuts, maize, oats, peas, potatoes, paprika, rye, soybeans, wheat
bromoxynil/terbuthylazine	C3/C1	Inhibition of photosynthesis at PS II	Nitrile/Triazine	Forage sorghum, grain sorghum, maize, sugarcane, sweetcorn
flumioxazin	E	Inhibition of PPO	N-phenylphthalimide	Apples, citrus, grapes, groundnuts, nectarines, peaches, pears, plums, prunes, soybeans, cotton
fomesafen	E	Inhibition of PPO	Diphenylether	Dry beans, green beans, groundnuts, soybean
oxadiazon	E	Inhibition of PPO	Oxadiazole	Apples, apricots, citrus, grapes, onions, rice, paprika, peaches, pears, plums, prunes, tobacco
oxyfluorfen	E	Inhibition of PPO	Diphenylether	Apples, apricots, broccoli, brussels sprouts, cabbage, cauliflower, garlic, onions, grapes, citrus, cherries, nectarines
pyraflufen-ethyl	E	Inhibition of PPO	Phenylpyrazole	Barley, wheat
saflufenacil/dimethenamid-P	E/K3	Inhibition of PPO / Inhibition of VLCFA	Pyrimidindione/Chloroacetamide	Maize, sugarcane
flurochloridone	F1	Bleaching: Inhibition of carotenoid biosynthesis at the phytoene desaturase step (PDS)	Other	Sunflower
isoxaflutole	F2	Bleaching: inhibition of 4-HPPD	Isoxaxole	Sugarcane
mesotrione	F2	Bleaching: Inhibition of 4-HPPD	Triketone	Maize, sugarcane

Active ingredient(s)	HRAC-Group	Mode of Action	Chemical family	Registered for use on the following crops
sulcotrione	F2	Bleaching: Inhibition of 4-HPPD	Triketone	Maize
topramezone	F2	Bleaching: Inhibition of 4-HPPD	Triketone	Maize
topramezone/dicamba	F2/O	Bleaching: Inhibition of 4-HPPD / Synthetic auxins	Triketone / Benzoic acid	Maize
mesotrione/s-metolachlor	F2/K3	Bleaching: Inhibition of 4-HPPD / Inhibition of VLCFAs	Triketone / Chloroacetamide	Maize
mesotrione/s-metolachlor/terbuthylazine	F2/K3/C1	Bleaching: Inhibition of 4-HPPD / Inhibition of VLCFAs / Inhibition of photosynthesis at PS II	Triketone / Chloroacetamide / Triazine	Sugarcane
clomazone	F3	Bleaching: Inhibition of carotenoid biosynthesis	Isoxazolidinone	Soybeans, tobacco
glyphosate/mesotrione/s-metolachlor	G/F2/K3	Inhibition of EPSP synthase/ Inhibition of 4-HPPD/Inhibition of VLCFAs	Glycine/Triketone/Chloroacetamide	RR-maize
glufosinate-ammonium	H	Glutamine syntetase inhibitor	Phosphinic acid	Tree nuts, stone fruit, pome fruit, wine and table grapes, citrus, potatoes, mangoes, pawpaws
oryzalin	K1	Microtubule assembly inhibition	Dinitroaniline	Apples, apricots, grapes, nectarines, peaches, pears, plums
pendimethalin	K1	Microtubule assembly inhibition	Dinitroaniline	Cotton, dry beans, groundnuts, kidney beans, potatoes, soybeans, sugarcane, sunflower, tobacco
trifluralin	K1	Microtubule assembly inhibition	Dinitroaniline	Apples, apricots, barley, cabbage, canola, carrots, cherries, chillies, citrus, cotton, cowpeas, dry beans, groundnuts, kidney beans, soybeans, sunflower, tomatoes, wheat, grapes
acetochlor*	K3	Inhibition of VLCFAs	Chloroacetamide	Groundnuts, maize, potatoes, sweetcorn, sugarcane, dry beans,, soybeans, cotton, forage sorghum,
dimethenamid-P	K3	Inhibition of VLCFAs	Chloroacetamide	Dry beans, grain sorghum, groundnuts, kidney beans, maize, potatoes, soybeans, sunflower, tobacco

Active ingredient(s)	HRAC-Group	Mode of Action	Chemical family	Registered for use on the following crops
metazachlor	K3	Inhibition of VLCFA	Chloroacetamide	Broccoli, Cabbage, Canola, dry beans, groundnuts, potatoes, soybeans, sugarcane, tobacco
metolachlor	K3	Inhibition of VLCFA	Chloroacetamide	Dry beans, groundnuts, maize, soybeans, sugarcane, sunflower, potatoes, kidney beans, green beans, lupines, grain sorghum, tobacco, forage sorghum
S-metolachlor	K3	Inhibition of VLCFA	Chloroacetamide	Cotton, dry beans, green beans, groundnuts, kidney beans, lupines, maize, grain sorghum, potatoes, forage sorghum, soybeans, sunflower
acetochlor/ametryn	K3/C1	Inhibition of VLCFAs / Inhibition of photosynthesis at PS II	Chloroacetamide / Triazine	Sugarcane
acetochlor/atrazine/simazine	K3/C1	Inhibition of VLCFAs / Inhibition of photosynthesis at PS II	Chloroacetamide / Triazine	Maize
acetochlor/atrazine/terbuthylazine	K3/C1	Inhibition of VLCFAs / Inhibition of photosynthesis at PS II	Chloroacetamide / Triazine	Maize
alachlor/atrazine	K3/C1	Inhibition of VLCFAs / Inhibition of photosynthesis at PS II	Chloroacetamide / Triazine	Maize
alachlor/prometryn	K3/C1	Inhibition of VLCFAs / Inhibition of photosynthesis at PS II	Chloroacetamide / Triazine	Potatoes, sunflower
S-metolachlor/terbuthylazine	K3/C1	Inhibition of VLCFA / Inhibition of photosynthesis at PS II	Chloroacetamide / Triazine	Apples, avocadoes, citrus, grain sorghum, grapes, maize mangoes
alachlor/linuron	K3/C2	Inhibition of VLCFAs / Inhibition of photosynthesis at PS II	Chloroacetamide / Urea	Potatoes
acetochlor/EPTC	K3/N	Inhibition of VLCFAs / Inhibition of lipid synthesis (not ACCase)	Chloroacetamide / Thiocarbamate	Maize
EPTC	N	Inhibition of lipid synthesis (not ACCase)	Thiocarbamate	Dry beans, kidney beans, potatoes, sunflower, maize, green beans, lucerne, leguminous pastures, sugarcane, sweetcorn, sweet potato,
2,4-D	O	Synthetic auxins	Phenoxy-carboxylic-acid	Grass pastures, Sugarcane, Wheat, Barley, grain sorghum, maize, rye, potatoes

Active ingredient(s)	HRAC-Group	Mode of Action	Chemical family	Registered for use on the following crops
2,4-D/dicamba	O	Synthetic auxins	Phenoxy-carboxylic-acid / Benzoic acid	Maize, sugarcane, wheat, grass pastures
2,4-DB	O	Synthetic auxins	Phenoxy-carboxylic-acid	Clover, lucerne, leguminous pastures, medics, wheat
dicamba	O	Synthetic auxins	Benzoic acid	Grain sorghum, maize, wheat
MCPA	O	Synthetic auxins	Benzoic acid	Apples, Barley, Grapes, Grass pastures, maize, peaches, pears, potatoes, rye, grain sorghum, sugarcane, wheat, oats
dicamba/topramezone	O/F2	Synthetic auxin / Inhibition of 4-HPPD	Benzoic acid / Triketone	Maize
bendioxide	C3	Inhibition of photosynthesis at PS II	Thiadiazine	Barley, chillies, dry beans, grain sorghum, green beans, green peppers, groundnuts, maize, oats, peas, potatoes, paprika, rye, soybeans, wheat
MSMA	Z	Unknown	Organoarsenical	Cotton, sugarcane

References

[1] Sauer JD. 1957. Recent migration and evolution of the dioecious amaranths. *Evolution* 11: 11–31

[2] Beckie HJ. 2006. Herbicide resistant weeds: management tactics and practices. *Weed Technol*. 2006: 20:793–814

[3] Webster TM, Nichols RL. 2012. Changes in the prevalence of weed species in the major agronomic crops of the southern United States: 1994/1995 to 2008/2009. *Weed Sci* 60: 145–157

[4] Norsworthy JK, Griffith G, Griffin T, Bagavathiannan M, Gbur EE. 2014. In-field movement of glyphosate-resistant Palmer amaranth (*Amaranthus palmeri*) and its impact on cotton lint yield: evidence supporting a zero-threshold strategy. *Weed Sci* 62: 237–249

[5] Ward SM, Webster TM, Steckel LE. 2013. Palmer Amaranth (*Amaranthus palmeri*): A Review. *Weed Technol.*27: 12-27

[6] Heap I. 2016. International survey of Herbicide-resistant weeds. http://www. weedscience.org/

summary/species.aspx.

[7] Guo P, Al-Khatib K. 2003. Temperature effects on germination and growth of redroot pigweed (Amaranthus retroflexus), Palmer amaranth (A. palmeri), and common waterhemp (A. rudis). *Weed Sci*. 51, 869–875.

[8] Horak MJ, Loughlin TM. 2000. Growth analysis of four Amaranthus species. *Weed Sci*. 48: 347–355

[9] Keeley PE, Carter CH, Thullen RJ. 1987. Influence of planting date on growth of Palmer amaranth (*Amaranthus palmeri*). *Weed Sci*. 35: 199–204.

[10] Sauer JD. 1955. Revision of the dioecious amaranths. *Madrono* 13:5–46

[11] Sosnoskie L M, Culpepper AS, Webster TM. 2011. Palmer amaranth seed mortality in response to burial depth and time. Pages 1550–1552 in 2011. Proceedings of the Beltwide Cotton Conference. Cordova, TN. National

[12] Smith DT, Baker RV, Steele GL. 2000. Palmer amaranth (*Amaranthus palmeri*) impacts on yield, harvesting, and ginning in dryland cotton (*Gossypium hirsutum*). *Weed Technol*. 14: 122–126

[13] Tedford EC, Fortnum BA. 1988. Weed hosts of Meloidogyne arenaria and Meloidogyne incognita common in tobacco fields in South Carolina. *Ann. Appl. Nematol*. 2: 102–105

[14] Price AJ, Balkcom KS, Culpepper SA, Kelton JA, Nichols RL, Schomberg H. 2011. Glyphosate-resistant Palmer amaranth: a threat to conservation tillage. *J. Soil Water Conserv*. 66: 265–275

[15] Van Zyl K. A guide for the control of weeds in South Africa. 3rd Edition. Published by AVCASA. 2017