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Inhibiting Effect of Shallow Seed Burial on Grass Weed Emergence

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Abstract

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The efficacy of superficial tillage as a sustainable tool to reduce the emergence of *Digitaria sanguinalis*, *Setaria viridis,* and *Sorghum halepense* was evaluated with field experiments. Seeds were buried at 1, 2, 5, and 10 cm of depth to simulate seed vertical distribution caused by autumn superficial tillage. Seedling emergence was monitored weekly for two years after sowing. The highest emergence was obtained in the first year after sowing and from 1 and 2 cm. *Sorghum halepense* was only slightly affected by seed burial, with 15% of emergence from 10 cm of depth, while *D. sanguinalis* was strongly affected, with 4% of emergence from 5 cm. The efficacy of superficial tillage as control tool could vary according to local weed flora.

Keywords: *Digitaria sanguinalis* (L.) Scop.; *Setaria viridis* (L.) Beauv.; *Sorghum halepense* (L.) Pers; conservation tillage; weed control; seedling emergence

Conservation tillage is based on the minimisation of soil disturbance, permanent soil cover by crop residues, and crop rotation (FAO 2012). In this system, various economic and environmental benefits come from the reduction of soil tillage (Holland 2004; Hobbs *et al*. 2008; Chauhan *et al.* 2012). However, the adoption of conservation agriculture requires modifications of weed management (Hobbs *et al.* 2008; Chauhan *et al.* 2012) because limited mechanical weed control forces the increase on herbicide dependence (Holland 2004; Hobbs *et al*. 2008; Chauhan *et al.* 2012). Seeds in conservation tillage systems after seed rain remain close to the soil surface among the crop residues (Refsell & Hartzler 2009) and are therefore directly exposed to environmental conditions and animal predation (Baraibar *et al.* 2009). Grass weed species (*Poaceae*) are well adapted to these environmental conditions, since they can produce a large number of seeds able to germinate few months after their dispersal, and represent some of the main weeds for conservation tillage systems. Moreover, biotypes resistant to different herbicide groups have been reported worldwide for various grass weeds (Scarabel *et al.* 2014). Difficulties in controlling grass weeds can cause a relevant seed rain and therefore a considerable seedling emergence in the subsequent cropping season. In those circumstances, occasional superficial soil tillage (up to 10–15 cm) could be proposed as an acceptable compromise to facilitate weed control by burying seeds in the deep soil layer, where the emergence conditions are less favourable without renouncing to most of the positive economic and environmental benefits of conservation agriculture. However, the efficacy of superficial soil tillage as weed control tool depends on the biological and ecologi-

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cal characteristics of the different grass species. For example, seed size determines the maximum depth from which seedlings can emerge (Benvenuti *et al.* 2001; Chauhan *et al.* 2006; Gardarin *et al.* 2010). Moreover, germination of grass species, which usually require fluctuating temperatures or light for dormancy break, could be reduced if deeply buried in the soil (Bullied *et al.* 2012; Batlla & Benech-Arnold 2014). The amplitude of daily temperature fluctuation is indeed maximum on the soil surface and rapidly diminishes with depth (Bullied *et al.* 2012; Loddo *et al.* 2015) and light usually only penetrates the first mm of the soil (Benvenuti & Macchia 1998). The various grass weed species can represent different seed bank persistence, however their seeds tend to largely germinate in the first years after dissemination and are usually characterized by reduced longevity in soil (Masin *et al.* 2006). Information on the emergence response of grass species from different burial depths could help evaluate the efficacy of superficial soil tillage as weed control tool in the conservation agriculture systems. Hence, this study investigates the emergence dynamics in a conservation agriculture scenario of three important grass weed species, *Setaria viridis* (L.) Beauv. (SETVI), *Sorghum halepense* (L.) Pers. (SORHA), and *Digitaria sanguinalis* (L.) Scop. (DIGSA), from different soil depths representing the range of seed burial caused by superficial soil tillage.

MATERIAL AND METHODS

Field experiment. Two field experiments were conducted from 2006 to 2009 at the experimental farm of the University of Padova at Legnaro (45°20'N, 11°58'E), north-eastern Italy. Fully ripened seeds of *S. viridis*, *S. halepense*, and *D. sanguinalis* were collected in the autumn of 2006 and 2007. Seeds were sown in mid-November 2006 and 2007 for the first and second experiment respectively at a set of fixed depths (1, 2, 5, and 10 cm) in plastic pipes buried in the soil. The burial depths were selected to simulate the seed vertical distribution caused by autumn superficial tillage. Three 200-seed replicates were included for each combination of species × depth with a completely randomized design. Pipes were filled with a silt loam soil (fulvi-calcaric Cambisol, FAO 2006) devoid of seeds of the studied species. There was no further soil disturbance throughout the duration of the experiments to simulate the conservation agriculture management. Emerged seedlings were counted and removed weekly from March to the end of August for two years after the sowing of each experiment. Daily rainfall and soil temperature at 0 cm depth were recorded throughout the duration of the experiments (2006–2009) by an ARPA (Regional Environmental Protection Agency) weather station and were similar to the average local trends. The climate at Legnaro is characterised by cold winters, hot summers, and a mean annual rainfall of about 850 mm.

Statistical analyses. Percentage of emerged seedlings was calculated out of the total number of buried seeds for each replicate at the end of each monitoring period corresponding to the first or second year after sowing (YAS hereafter) of each experiment. Means and relative standard error of percentage of annual and total (YAS 1 plus YAS 2) emergence were estimated for each combination of species × depth.

Factorial ANOVA ($P < 0.05$) was performed to evaluate the effect of sowing years, species, depth, YAS and their interaction on total and annual emergence. Tukey's HSD test ($P < 0.05$) was adopted to identify significant differences among means. All statistical analyses were done using of the statistical package Statistica Version 10 (StatSoft, Tulsa, USA).

RESULTS

Significant effects of sowing year, species, depth, YAS and their interaction were detected on percentage of total and annual emergence. No differences were identified between the two sowing years (2006 and 2007) except for *S. halepense*, that achieved higher total emergence for sowing year 2007 compared to 2006 (52.2 ± 8.50% vs 33.4 ± 3.24%). *Sorghum halepense* and *S. viridis* reached higher total emergence than *D. sanguinalis* (Figure 1). Regarding depths, total emergence was significantly higher for seeds buried at 1 and 2 cm depths compared to 10 cm of depth for all species (Figure 2). Considering the annual emergence obtained for each depth independently, the highest values were observed for 1 and 2 cm of depth especially in YAS 1 for the three species (Figure 3). Emergence of *D. sanguinalis* was notably affected by burial depth, with the lowest emergence from 5 cm (3.6 ± 1.09%) in comparison with the other species (Figure 2). No differences were observed between the emergence of *D. sanguinalis* obtained for seeds buried at depths of 1 and 2 cm and for

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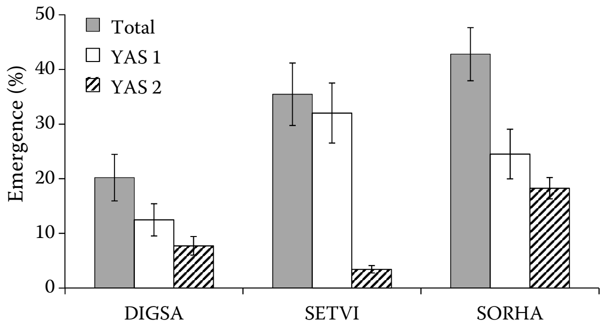

Figure 1. Percentages of emergence of *D. sanguinalis* (DIGSA), *S. viridis* (SETVI), and *S. halepense* (SORHA) during the year after sowing (YAS) 1 and 2 compared with percentages of total and average annual emergence. Values are means of each treatment (n = 24; df = 96 for YAS 1 and YAS 2; n = 24, df = 48 for total emergence; n = 48, df = 96 for average annual emergence). Vertical bars represent standard errors

YAS 1 and YAS 2 (Figures 1 and 2). *Setaria viridis* presented also a relevant reduction of emergence as burial depth increased, passing from percentages of emergence around 60% from 1 and 2 cm of depth to less than 20% of emergence from 5 cm and less than 2% from 10 cm (Figure 2). Moreover, almost 90% of total emergence was observed during YAS 1 (Figure 1). *Sorghum halepense* was the species least affected by burial depth, presenting no significant differences among the relevant percentages of emergence obtained at 1, 2, and 5 cm and confirming its capability to emerge even from a depth of 10 cm (Figure 2). The proportion of total emergence between YAS 1 and YAS 2 varied according to burial depth for *S. halepense* (Figure 3). The greatest annual emergence from depths of 1 and 2 cm was recorded during YAS 1 after some months of winter burial, while annual emergence from 5 cm was indeed similar during YAS 1 and YAS 2 and seedling emergences from 10 cm were observed principally during YAS 2 after more than a year of seed burial

DISCUSSION

The findings of the present study confirmed that the inhibiting effect of increasing burial depth on seedling emergence varied among the different weed species, with a positive influence of seed weight as already reported by previous studies (Benvenuti *et al.* 2001; Chauhan *et al.* 2006; Gardarin *et al.* 2010). *Sorghum halepense*, the largest-seeded of the

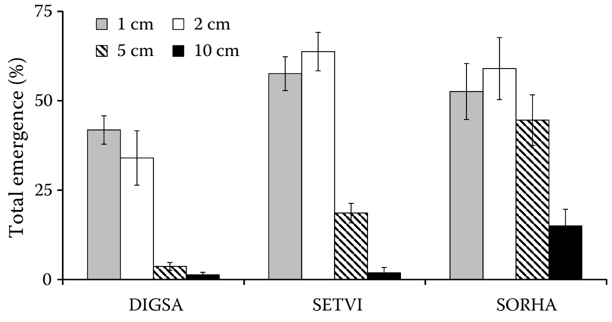

Figure 2. Percentages of total emergence of *D. sanguinalis* (DIGSA), *S. viridis* (SETVI), and *S. halepense* (SORHA) from different burial depths of 1, 2, 5, and 10 cm. Values are means of each treatment (n = 6; df = 48). Vertical bars represent standard errors

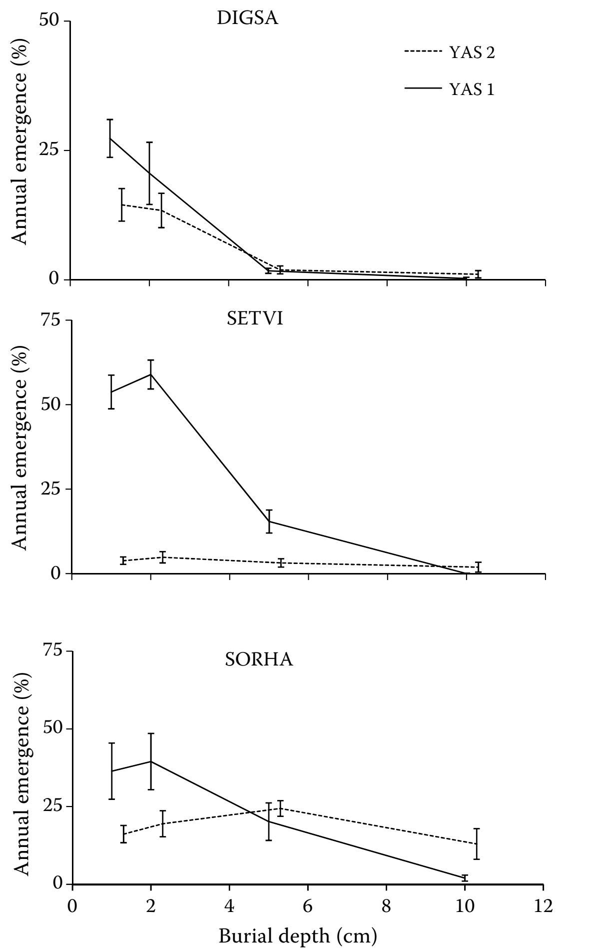

Figure 3. Percentages of annual emergence of *D. sanguinalis* (DIGSA), *S. viridis* (SETVI), and *S. halepense* (SORHA) during the year after sowing (YAS) 1 and 2 from different burial depths of 1, 2, 5, and 10 cm. Values are means of each treatment (n = 6; df = 96). Vertical bars represent standard errors

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studied species, presented a reduced depth-mediated emergence inhibition. This reduced emergence was probably a consequence of different factors such as seed decay or predation before germination, fatal germination and depth-mediated induction of seed dormancy. Depth-mediated induction of seed dormancy is a consequence of the perception of unfavourable conditions for germination due to excessive seed burial depth and is considered a strategy to limit fatal germination and extend longevity and persistence of the seedbank. Martinková and Honěk (2013) reported for example a relevant reduction of germination for *Echinochloa crus-galli* (L.) P. Beauv, another spring emerging grass weed, if burial depth increased from 2 cm to 10 cm. Since non-germinated seeds were not recovered from the soil at the end of this study, it was not possible to measure the percentage of seed decay, fatal germination, and dormant seeds after the two years of burial. Dormant seeds proved to be the main cause of reduced emergence for *D. sanguinalis* and *S. halepense* for short term experiments (Benvenuti *et al*. 2001), while the incidence of seed decay and fatal germination was reported to increase during prolonged seed burial reducing for example seed viability of *S. viridis* and *D. sanguinalis* to less than 1% of original seed number after 3 years of burial (Masin *et al.* 2006). However, some interesting indications and conclusions on the efficacy of superficial soil tillage as weed control tool for the studied species can be drawn by analysing their different behaviour.

The relevant emergence observed for *S. halepense* from 5 cm depth and to a lesser extent from 10 cm confirmed the limited sensibility of this species to seed burial in accordance with the findings by Benvenuti *et al*. (2001). However, it is also interesting to consider the notable variation of the annual emergence between YAS 1 and YAS 2 according to burial depth. Superficial depths probably presented more favourable conditions, i.e. a higher amplitude of temperature fluctuation, which allowed a larger proportion of seeds to break dormancy and germinate in the first spring after burial. Environmental conditions became less favourable with the increase of burial depth and seeds required a longer period of burial to germinate. Seeds buried at a 10 cm depth probably required a prolonged deposition in the soil to relief from dormancy and germinate at those environmental conditions. According to the observed behaviour, superficial soil tillage cannot be considered as an effective control tool for *S. halepense*. Seeds buried in the superficial soil layers would in fact produce large emergence flushes during the first 1–2 years after the tillage, while deeply-buried seeds would instead start to germinate from the second year, extending seedbank longevity but also the number of years with relevant weed infestation. Moreover, increasing burial depth has been observed to markedly extend the emergence period for *S. halepense* seedlings (data not shown), as already reported by Benvenuti *et al*. (2001). In this scenario, postponing or even repeating the herbicide application could be necessary to control the initial emergence flushes of *S. halepense* to avoid a large yield loss (Page *et al*. 2012) and to kill the late-emerging seedlings which would otherwise produce seeds and greatly increase the superficial seedbank (Bagavathiannan & Norsworthy 2012). In the case of heavy *S. halepense* seed rain, avoiding soil disturbance could be therefore suggested to maintain seeds close to soil surface in order to increase their annual germination, reduce their longevity, and particularly limit the seedling emergence period.

The temporal dynamics of *S. viridis* emergence observed during the present experiment confirmed the results by Masin *et al.* (2006) who similarly described a very high germinability for this species in the first spring after burial, while seed viability declined to 60% of the initial after one year of burial. It may be supposed that also in the present study most buried *S. viridis* seeds were released from dormancy after the first winter of burial and germinated, consequently a high seedling emergence was observed from the superficial burial depths during YAS 1. The main cause of reduced emergence was probably the fatal germination during YAS 1 and seed decay or predation in the subsequent months, and *S. viridis* emergence was consequently limited during YAS 2. Considering also the limited emergence observed from 5 and 10 cm of depth, superficial soil tillage could therefore represent an effective control tool for *S. viridis,* especially if machinery able to bury most of the seeds below a 5 cm depth would be applied. It is also important to maximise the control of seedlings emerged during the first year to avoid further seed rain and accelerate the natural seedbank depletion for this species.

The relevant inhibiting effect of the seed burial on the emergence of *D. sanguinalis* observed during this field experiment is in agreement with previous laboratory experiments (Benvenuti *et al.* 2001; Gardarin *et al.* 2010). Masin *et al*. (2006) described high germinability for this species after the first winter burial, similar to that of green foxtail,

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but the smaller seed size and seed stored reserves, and the limited shoot diameter and length of this species (Gardarin *et al.* 2010) probably penalised *D. sanguinalis* emergence from depths below 5 cm. Superficial soil tillage could therefore be an effective control tool for *D. sanguinalis* in conservation agriculture systems since seedbank of this species is normally subjected to fast depletion if seed rain is avoided because seed viability dramatically decreases after two years of burial (Masin *et al.* 2006). However, *D. sanguinalis* seeds usually exit dormancy and germinate progressively later than many other grass weeds, hence emergence flushes of this species can extend to summer months (Masin *et al.* 2006). Late-emerging seedlings often appear after the herbicide application so they can complete their cycle and refill the superficial seedbank, making the complete eradication of this species very difficult. *Sorghum. halepense*, *D. sanguinalis*, and *S. viridis* presented diverse deep-mediated inhibition of emergence and consequently superficial soil tillage could have a different control effect on them. Morphological traits such as seed size could have played an important role in this process but also ecological aspects, such as dormancy level, sensitivity to and dependence on environmental factors (i.e. fluctuating temperatures, light, O_2 concentration) to break seed dormancy and promote germination should be considered. The efficacy of superficial soil tillage as control tool for grass weeds in conservation tillage systems should be evaluated therefore according to the biological and ecological characteristics of the local weed flora. Moreover, superficial soil tillage should be considered not as an alternative to chemical herbicide but as a part of a wider complex of tools and strategies, such as crop density or arrangement (Simić *et al*. 2012), aimed to reduce the environmental impact of weed control and guarantee a satisfactory crop yield.

References

Bagavathiannan M.V., Norsworthy J.K. (2012): Late-season seed production in arable weed communities: Management implications. Weed Science, 60: 325–334.

Baraibar B., Westerman P.R., Carrión E., Recasens J. (2009): Effects of tillage and irrigation in cereal fields on weed seed removal by seed predators. Journal of Applied Ecology, 46: 380–387.

Batlla D., Benech-Arnold R.L. (2014): Weed seed germination and the light environment: Implications for weed management. Weed Biology and Management, 14: 77–87.

Benvenuti S., Macchia M. (1998): Phytochrome-mediated germination control of *Datura stramonium* L. seeds after seed burial. Weed Research, 38: 199-205.

Benvenuti S., Macchia M., Miele S. (2001): Quantitative analysis of emergence of seedlings from buried weed seeds with increasing soil depth. Weed Science, 49: 528–535.

Bullied W.J., Van Acker R.C., Bullock P.R. (2012): Review: Microsite characteristics influencing weed seedling recruitment and implications for recruitment modeling. Canadian Journal of Plant Science, 92: 627–650.

Chauhan B.S., Gill G., Preston C. (2006): Seedling recruitment pattern and depth of recruitment of 10 weed species in minimum tillage and no-till seeding systems. Weed Science, 54: 658–668.

Chauhan B.S., Singh R.G., Mahajan G. (2012): Ecology and management of weeds under conservation agriculture: a review. Crop Protection, 38: 57–65.

FAO (2006): World Reference Base for Soil Resources 2006. A Framework for International Classification, Correlation and Communication. FAO World Soil Resources Reports 103. Rome, Food and Agricultural Organization of the United Nations.

FAO (2012): Available at http://www.fao.org/ag/ca/doc/FLYER_Conservation_Agriculture.pdf (accessed July 28, 2015).

Gardarin A., Dürr C., Colbach N. (2010): Effects of seed depth and soil aggregates on the emergence of weeds with contrasting seed traits. Weed Research, 50: 91–101.

Hobbs P.R., Sayre K., Gupta R. (2008): The role of conservation agriculture in sustainable agriculture. Philosophical Transactions of the Royal Society B, 363: 543–555.

Holland J.M. (2004): The environmental consequences of adopting conservation tillage in Europe: reviewing the evidence. Agriculture, Ecosystem, Environment, 103: 1–25.

Loddo D., Masin R., Gasparini V., Meggio F., Pitacco A., Zanin G. (2015): Assessing microclimate conditions of surface soil layers to improve weed emergence modelling. Italian Journal of Agrometeorology, 20 (Issue 2): 19–26.

Martinková Z., Honěk A. (2013): Fatal Germination in Barnyardgrass (*Echinochloa crus-galli*). Plant Protection Science, 49: 193–197.

Masin R., Zuin M.C., Otto S., Zanin G. (2006): Seed longevity and dormancy of four summer annual grass weeds in turf. Weed Research, 46: 362–370.

Page E.R., Cerrudo D., Westra P., Loux M., Smith K., Foresman C., Wright H., Swanton C.J. (2012): Why early season weed control is important in maize. Weed Science, 60: 423–430.

Refsell D.E., Hartzler R.G. (2009): Effect of tillage on common waterhemp (*Amaranthus rudis*) emergence and

doi: 10.17221/78/2015-PPS

vertical distribution of seed in the soil. Weed Technology, 23: 129–133.

Scarabel L., Panozzo S., Savoia W., Sattin M. (2014): Target-Site ACCase-resistant johnsongrass (*Sorghum halepense*) selected in summer dicot crops. Weed Technology, 28: 307–315.

Simić M., Dolijanović Ž., Maletić R., Stefanović L., Filipović M. (2012): Weed suppression and crop productivity by different arrangement patterns of maize. Plant, Soil and Environment, 58: 148–153.

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