AlertInf: emergence predictive model for weed control in maize in Veneto

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Abstract: *Weed control is one of the most important management practices in maize production. Weed time of emergence influences the weed-crop competition, determining the level of damage that the infestation may cause to crop yield. The ability to predict weed emergences can help to optimize control timing, increasing the efficacy of both chemical and mechanical methods and consequently reducing herbicide use. The Department of Environmental Agronomy and Crop Science of the University of Padova has developed the* ***AlertInf*** *model, which provides the percentage of emergence reached by a given weed species in real time using meteorological data, such as soil temperature and rainfall. The Agrobiometeorology Unit of ARPA Veneto has organized an interactive support service using the* ***AlertInf*** *model on their webpage www.arpa.veneto.it/upload_teolo/agrometeo/infestanti.htm to help farmers in planning weed control.*
Keywords: *emergence prediction, weed emergence dynamic, annual weeds, support service*

Riassunto: *La gestione delle infestanti è una delle pratiche più importanti nella coltivazione del mais. Il tempo di comparsa delle malerbe influenza la competizione tra infestante e specie coltivata determinando l'entità del danno che l'infestazione può provocare in termini di resa della coltura. La capacità di prevedere le emergenze delle malerbe può aiutare ad ottimizzare i tempi di controllo, può aumentare l'efficacia dei metodi usati sia chimici che meccanici e di conseguenza può ridurre l'uso degli erbicidi. Il Dipartimento di Agronomia Ambientale e Produzioni Vegetali dell'Università di Padova ha sviluppato il modello* ***AlertInf*** *in grado di fornire la percentuale di emergenza raggiunta da una data specie infestante in tempo reale usando dati meteorologici come temperatura del suolo e pioggia. L'U.O. di Agrobiometeorologia dell'ARPA Veneto utilizzando il modello* ***AlertInf*** *ha organizzato un servizio di assistenza interattivo alla pagina web www.arpa.veneto.it/upload_teolo/agrometeo/infestanti.htm per aiutare gli agricoltori nella programmazione degli interventi di controllo delle infestanti.*
Parole chiave: *previsione delle emergenze, dinamica di emergenza delle infestanti, malerbe annuali, servizio di assistenza*

INTRODUCTION

Maize is one of the most important crops of the Po Valley. It is traditionally rotated with winter wheat and other crops. However, in the last years the evolution in farming techniques has resulted in the increasing abandonment of traditional rotations, with maize being quite often the only crop cultivated over large areas (Giupponi, 2000).
Traditionally, the sowing period is between late April and early May. In recent years, there has been a trend towards anticipating maize sowing in northern Italy from mid-April to mid-March, with many agronomic advantages, but also alterations of weed flora composition, density and time of emergence, which obviously affect weed control (Otto et al., 2009).

In Po Valley, the highest pesticide load comes from herbicide applications, which is estimated to be practiced in 96% of the total maize area. Different strategies are used: only pre-emergence (52% of total maize area treated), only post-emergence (7,5%) or pre and post-emergence (40%) applications (Meissle et al., 2010). Recent studies (Rapparini et al., 2006) and the authors' personal experience suggest that the pre+post-emergence treatment strategies provide the best weed control, but one treatment can often be sufficient and in these cases a post-emergence treatment is better than just one pre-emergence treatment, but only if it is carried out at the proper time. The correct timing of either chemical or mechanical control is indispensable for maximizing its efficacy (Dogan et al., 2004). Knowing the dynamics of weed emergence means being able to estimate how many weeds can be eliminated by a treatment done today and how many will escape by emerging later, thus supporting decision making about the timing of treatments. There have been many studies on emergence dynamics with the aim of creating models that can predict the timing of weed emergence. The first generation of prediction models were based on the

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concept of Growing Degree Days (GDD) or thermal time (Satorre et al., 1985; Bewick et al., 1988; Tan et al., 2000). Emergence dynamics were described considering temperature as the only factor influencing the germination-emergence stages. The more recent models also consider soil water potential as a factor that, along with temperature, can regulate emergence. They are based on the concept of "hydrothermal time" (Gummerson, 1986; Bechini et al., 2004; Larsen et al., 2004; Alvarado and Bradford, 2005; Ekeleme et al., 2005; Leguizamon et al., 2005, Kochy and Tielborger, 2007; Finch-Savage et al., 2008). This latter concept has notably improved the prediction capacity and provided a suitably robust method for understanding how environmental factors interact to determine a given emergence dynamics over time (Bradford, 2002). These models are based on ecophysiological parameters, such as base temperature and base water potential, which depend on the ecotype analyzed, so models created in a given environment require a revaluation of the factors involved and recalibration of the parameters prior to being transferred to another site. Using the existing models as a starting point, a study was initiated to produce a model adapted to environment and management systems in Veneto Region for advising farmers on weed control in maize. The first result of this research is **AlertInf**, a model for predicting emergences of the principal weeds in maize adopted and organized in 2008 as an interactive web service for farmers in the Veneto Region.

Tab. 1 - Parameters used to calculate hydrothermal time and the Gompertz equation.
Tab. 1 - Parametri utilizzati per il calcolo del tempo idrotermico e della funzione Gompertz.

Weed species	Tb (°C)	X (days)	P_{limit} (mm)	a	b
A. retroflexus	12.6	10	5	4.58	0.088
C. album	5.0	10	0.3	7.30	0.016
S. halepense	12.3	10	1.6	4.48	0.081

MODEL DEVELOPMENT

Constructing the model required laboratory tests for calculating the base temperature, the threshold level beneath which germination does not occur. This was estimated according to the method of Masin et al. (2005).

Field experiments were done from 2002 to 2006 to study the emergence dynamics needed to create the model and then field trials were performed in 2007 to validate the model. All experiments were conducted in maize fields of the Veneto Region and consisted of floristic surveys carried out in three plots measuring five rows wide by 5 m long, where weeds were allowed to remain for the whole crop growing season. In these plots, 12 quadrats of 0.75 x 0.10 m, four for each plot, were fixed on the soil perpendicular to the row. Weed seedlings in these areas were

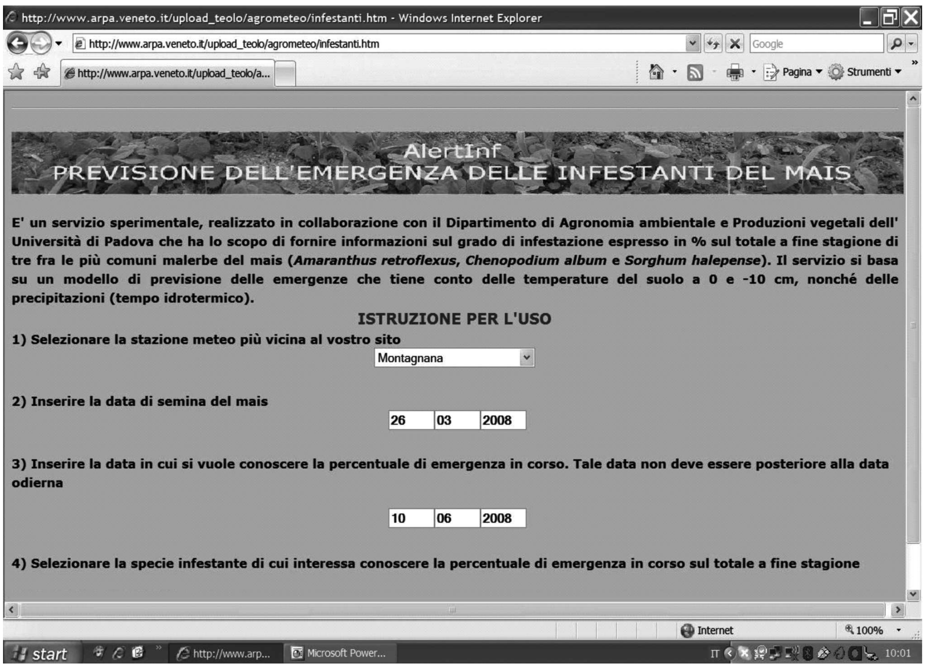

Fig. 1 - Initial screen of the **AlertInf** model in the ARPA Veneto website.
*Fig. 1 - Schermata iniziale del modello **AlertInf** nel sito web dell'ARPA Veneto.*

counted, classified and removed weekly. At the end of the growing season cumulated emergence data were used to create or validate the model.
The formula for calculating hydrothermal time is:

$$GDD = \sum (n \cdot \max(Tsm_i - Tb, 0) + GDD_{i-1} \qquad (1)$$

where Tsm_i (°C) is the soil temperature given by the average of the daily temperatures at 0 and -10 cm, Tb (°C) is the base temperature, x is the number of days to consider for calculating the rainfall limit and P_{limit} (mm) is the minimum total rainfall during x preceding days required to produce emergences. n = 0 if the total rainfall in the past x days is lower than P_{limit} and n = 1 if the it is higher than P_{limit}.
The input data required by the model were obtained from soil temperature and daily rainfall data measured at the ARPAV weather stations. The soil temperature probes used high sensitivity linearity thermoresistors called LTN, due to their higher range of resistance (ohm) than PT100 or NTC. Rainfall was measured by a standard Tipping Bucket Rain Gauge with double switch electric pulse counter.
The accumulation of hydrothermal time starts from the maize sowing date. The base temperature, estimated in a seed germinator, and minimum rainfall amounts required for germination, estimated on the basis of the field trials, are reported in Table 1 for the three weeds currently included in the model: *Amaranthus retroflexus* L., *Chenopodium album* L. and *Sorghum halepense* (L) Pers. When hydrothermal time has been calculated, the cumulated emergence percentage is determined with a Gompertz equation:

$$ET = 100 \cdot \exp[-a \cdot \exp(-b \cdot GDD)] \qquad (2)$$

where *a* represents a GDD lag before emergence starts, and *b* represents the rate of increase of emergence once it is initiated. *a* and *b* depend on the species (Tab. 1).
The program is available on the internet at www.arpa.veneto.it/upload_teolo/agrometeo/infestanti.htm. Java programming language was adopted to implement the script part of the webpage.

ILLUSTRATIVE RESULTS

The program available on the internet is simple and intuitive. The user must only select one or more weed species of interest, indicate the location of the farm to automatically download the data from the nearest weather station, and lastly insert the maize sowing date (Fig. 1). After these simple operations the model calculates the percentage of emergence of the selected weed species.
The information provided by **AlertInf** is the percentage of weeds that have already emerged out of the total number of plants that may potentially emerge during the season (Fig. 2). This information is useful for

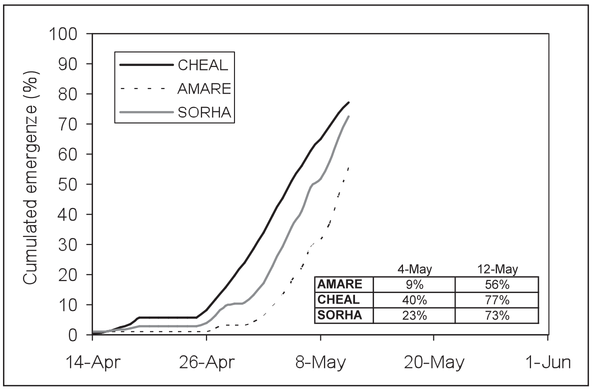

Fig. 2 – The model output is the percentage of emergence reached in the field by the selected species. This information is useful to make a more accurate decision on weed control. Supposing that on May 4th **AlertInf** shows an emergence of 40% or less reached by the three species in the field: on this basis, it can be predicted that many weeds (more than 60%) will emerge over the next few days, so it would be advisable not to treat. Seven days later **AlertInf** indicates an average of 70% of emergence, so the decision can be made to treat. In this case, having waited for a week has meant significantly reducing the number of weeds that would have emerged later and so a second treatment is unnecessary.
*Fig. 2 – L'output del modello è la percentuale di emergenza raggiunta in campo dalla specie selezionata. Tale informazione è utile per decidere più accuratamente il tempo di l'intervento. Supponiamo che il 4 maggio **AlertInf** mostri una percentuale di emergenza raggiunta in campo dalle tre specie uguale o inferiore al 40%. Sulla base di tale dato si prevede che molte infestanti (più del 60%) emergeranno nei giorni successivi, è quindi consigliabile non intervenire. Sette giorni dopo **AlertInf** indica una percentuale di emergenza aumentata mediamente al 70%, quindi si può decidere di intervenire. In questo caso aver atteso una settimana prima di trattare ha significato ridurre notevolmente il numero di infestanti che sarebbero emerse dopo il trattamento e quindi aver evitato un secondo intervento.*

correctly timing the control, either chemical or mechanical, maximizing its efficacy and avoiding a further treatment, with a saving in time and money. For example, if today **AlertInf** displays a low emergence percentage of a given weed, it means that the control treatment will only eliminate these few emerged plants and that the majority of the infestation can be expected to emerge afterwards, so another treatment will be required to avoid a crop yield loss. On the contrary, if the treatment is done when the estimated percentage of emergence is high, for example 70-80% (WeedCast Version 4.0 Documentation), many weeds will be controlled and only a few will emerge later, so no second treatment will be needed.
Unlike decision-support systems (Berti et al., 2003), which identify if a treatment is necessary or not, listing the best solution or solutions, the information provided by **AlertInf** is not advice to be followed, but it has instead to be interpreted by the farmer. **AlertInf**

provides the percentage of emergence of the potential infestation in the field at the end of the season. This means that the model does not display an absolute number of plants per square metre but just a percentage, with the corresponding density depending on the field. Because a given infestation percentage can have a different significance depending on the density a species may reach in the field, it is not possible to give associated advice. It is the farmer who must interpret the information on the basis of what he sees and knows about his own field. Another limitation of the **AlertInf** model is that it does not provide information on the phenological stage (number of true leaves) that the already emerged weeds have reached, whereas each herbicide has a phenological stage limit beyond which its efficacy is much lower. Therefore, once the percentage of emergence has been verified with **AlertInf**, it is important to check the phenological stage reached by the species in the field before deciding whether to wait a few days before treating. **AlertInf** is therefore not a model that gives advice, but just information in support of the farmer's own experience.

FUTURE DEVELOPMENTS

The model has only been made available to farmers by the ARPAV Agrobiometeorology Unit in 2008, so it is not yet possible to make any observations on the responses of the users, who are themselves evaluating the service. The model currently only gives information for three species, but another six important weeds in maize are now being studied, and will soon be added to **AlertInf**: *Abutilon theophrasti* Medik., *Digitaria sanguinalis* (L.) Scop., *Echinochloa crus-galli* L.) Beauv., *Polygonum persicaria* L., *Setaria viridis* (L.) Beauv., *Solanum nigrum* L.. The model only predicts emergence in non-irrigated maize, another improvement to the service will be the possibility of predicting emergence in irrigated maize; indeed it will soon be possible to insert the irrigating calendar, which will be added to the rainfall for the calculation of hydrothermal time.

Weed research is on-going to further our understanding of weed germination, emergence and early growth. Future versions of **AlertInf** will incorporate the results from these studies allowing us to expand and improve the model according to user requests.

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