WheatPot: A simple model to simulate grain yield potential of spring wheat

I- Model description and evaluation

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I- مدل WheatPot: مدل ساده برای یک‌پلاک‌کشی ال‌پی‌آئی عملکرد دانه گندم بهاره

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عموماً، مزرعان‌های تازه‌کاری معمولاً از عوامل مؤثر بر رشد گیاه را در خصوص و در اثر مصرف زراعات صورت گرفته‌اند. محدودیت‌های سازی توان از دسترس محدودیت‌هایی که تاکنون از آن روش برای بررسی اثر تغییر خورشیدی و در جدید بررسی عوامل گردید (Spaeth, 1987) (Sheehy et al., 1990) و بررسی استفاده شده (Pirmoradian و Sepaschka, 2005).

در اثر مدل‌های زراعت معمولاً رسیدگی گاه براساس داده‌های اب و هوای (روزانه، هفته، سالی) به عنوان محدودیت‌های دسترسی به داده‌های اب و هوای. این اثرات جهت‌گذاری بر روی خاصیت عوامل مدل‌های زراعت مدل‌های زراعت کاهش داده‌اند که برای اهداف مختلف می‌تواند. استفاده (Timsina و Hympehys, 2006) از این مدل‌ها چندان استفاده‌ای دارد.
WheatPot: A Mathematical Model for Wheat Growth and Development (Zadoks et al., 1974) has been widely adopted in subsequent studies. Zadoks and his colleagues proposed the model based on a series of assumptions and observations about plant growth and development. The model has been modified and improved by many researchers over the years.

In this study, we aim to evaluate the performance of the WheatPot model and its ability to accurately simulate the growth and development of wheat under various environmental conditions. We conducted experiments under controlled conditions and compared the model predictions with the observed data. Our results show that the model performs well in predicting key growth parameters such as grain yield and harvest index.

Materials and Methods

The WheatPot model was calibrated using data from a series of experiments conducted at different locations and under varying environmental conditions. The model parameters were adjusted to minimize the difference between the predicted and observed values.

Results

The model predictions were found to be in good agreement with the observed data. The results showed that the model is able to accurately predict the growth and development of wheat under different conditions. The model also demonstrated its capability to simulate the effects of various environmental factors on wheat growth.

Conclusion

The WheatPot model is a valuable tool for predicting wheat growth and development under different environmental conditions. Its accuracy and reliability make it a useful tool for crop management and planning.

References


Ehdaie and Wains, 2001


Radiation Use Efficiency (RUE) is a measure of the efficiency with which plants convert solar radiation into biomass. In this study, we used the concept of RUE to evaluate the performance of the WheatPot model.

Photosynthetic Active Radiation (PAR) is the range of electromagnetic spectrum that is most effective in driving photosynthesis. In this study, we used PAR to estimate the amount of radiation available for photosynthesis.

In conclusion, the WheatPot model is a powerful tool for predicting wheat growth and development. Its accuracy and reliability make it a valuable tool for crop management and planning.
<table>
<thead>
<tr>
<th>Location and Years</th>
<th>Location and Years</th>
<th>Latitude and Longitude</th>
<th>Treatments</th>
<th>Cultivars</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ahvaz 2003-2004</td>
<td>Ahvaz 2004-2005</td>
<td>31° 21′ N 48° 8′ E</td>
<td>Cultivar</td>
<td>Fong, Chamran, Star</td>
</tr>
<tr>
<td>Ramin University 2004-2005</td>
<td>Ramin University 2004-2005</td>
<td>31° 36′ N 48° 41′ E</td>
<td>Cultivar</td>
<td>Fong, Chamran, Star</td>
</tr>
<tr>
<td>Bostan 2004-2005</td>
<td>Bostan 2004-2005</td>
<td>31° 4′ N 48° 0′ E</td>
<td>Cultivar</td>
<td>Fong, Chamran, Star</td>
</tr>
</tbody>
</table>

**Fig. 1. Algorithm for WheatPot model**
Fig. 2. Relationship between development index and fraction of intercepted radiation

\[ Y = HI \times RUE \sum_{i=1}^{n} \left( \frac{Q_{dPARi} \times P_i \times F_i}{\Delta Ei} \right) \]

\[ F = \frac{a}{1 + \exp\left(\frac{b - DV1}{c}\right)} \]

Where:
- \( Y \) is the fraction of intercepted radiation,
- \( HI \) is the development index,
- \( RUE \) is the radiation use efficiency,
- \( Q_{dPARi} \) is the daily PAR intercepted by the crop,
- \( P_i \) is the PAR penetration factor,
- \( F_i \) is the fraction of intercepted radiation at stage \( i \),
- \( \Delta Ei \) is the energy difference between stages \( i-1 \) and \( i \),
- \( a, b, c \) are constants.

This relationship was adapted from Ewert et al. (1999) and Sheehy et al. (2004) to simulate the development of wheat using the WheatPot model.
Fig. 3. Temperature response of development rate
Table 1. Correspondence of development index (DVI) to Zadoks stages (ZS)

<table>
<thead>
<tr>
<th>Zadoks Scale</th>
<th>Development Index</th>
<th>Commencement of stage</th>
<th>Shrouded Stage</th>
<th>Stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>-1.0</td>
<td>Sowing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.5</td>
<td>-0.5</td>
<td>Germination</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10.00</td>
<td>0.0</td>
<td>Emergence</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14.22</td>
<td>0.20</td>
<td>Spiklet Initiation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30.00</td>
<td>0.45</td>
<td>Terminal Spiklet</td>
<td></td>
<td></td>
</tr>
<tr>
<td>40.00</td>
<td>0.65</td>
<td>Flag Leaf</td>
<td></td>
<td></td>
</tr>
<tr>
<td>50.00</td>
<td>0.90</td>
<td>Spike Emergence</td>
<td></td>
<td></td>
</tr>
<tr>
<td>60.00</td>
<td>1.00</td>
<td>Anthesis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>70.00</td>
<td>1.15</td>
<td>Milky grain</td>
<td></td>
<td></td>
</tr>
<tr>
<td>80.00</td>
<td>1.50</td>
<td>Doughy grain</td>
<td></td>
<td></td>
</tr>
<tr>
<td>90.00</td>
<td>1.95</td>
<td>Physiological Maturity</td>
<td>Ripening</td>
<td></td>
</tr>
<tr>
<td>92.00</td>
<td>2.00</td>
<td>Maturity</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Teshshen Xoura راد شده به سطح زمین به عنوان ورودی مدل مذکور است. لازم است که ساعات افتتاح موجود به تنش تنش Xoura راد به شرح (FAO 56) استفاده کردد، که در آن زمان مدل از رابطه انکسترا برای ورودی بر اساس ساعات افتتاح استفاده شده است (Wang and Engel, 1998).

\[
Ra = 37.6 \, dr (Ws \sin \lambda \cdot \sin \delta + \cos \lambda \cdot \cos \delta \cdot \sin Ws)
\]

(7)

\[
Ws = \arccos(-\tan \lambda \cdot \tan \delta)
\]

(8)

\[
dr = 1 + 0.033 \cos (0.0172J)
\]

(9)

\[
\delta = 0.409 \sin (0.0172J - 1.39)
\]

(10)

\[
J = \text{integer} (30.5M - 14.6)
\]

(11)

\[
N = 7.64 \, Ws
\]

(12)

\[
Rs = 0.77 (0.25 + 0.5 \frac{n}{N}) \, Ra
\]

(13)

\[
PAR = Rs \times 0.5
\]

(14)
عنوان ورودی برای اجرای مدل استفاده شدن در این مطالعه کاشت‌گاه‌های احواز طی آزمایش زراعی و تشکیل‌های SHH و MJ m-2 d-1 و شرح جدول به دست امتداد.

پارامترهای جدول از ارقام کنند که به شرح
تایید می‌شود.

جدول - Table 3. The physiological traits of wheat cultivars

| کشت‌گاه | حداکثر (MJ m-2 d-1) | حداکثر (MJ m-2 d-1) | کارآی صرف نور (MJ m-2 d-1) | شاخه برداشت | جنگل | هدف | جدول | روش
<table>
<thead>
<tr>
<th></th>
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<th></th>
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</thead>
<tbody>
<tr>
<td>فونگ</td>
<td>1100</td>
<td>872</td>
<td>0.0143</td>
<td>0.0232</td>
<td>0.0143</td>
<td>872</td>
<td>1100</td>
<td>40</td>
</tr>
<tr>
<td>Chamran</td>
<td>1262</td>
<td>895</td>
<td>0.0126</td>
<td>0.0244</td>
<td>0.0115</td>
<td>895</td>
<td>1262</td>
<td>39</td>
</tr>
<tr>
<td>ستار</td>
<td>1280</td>
<td>1017</td>
<td>0.0115</td>
<td>0.0244</td>
<td>0.0115</td>
<td>1017</td>
<td>1260</td>
<td>36</td>
</tr>
</tbody>
</table>

تایید کننده: جدول ۳ تایی کشت‌گاه‌های بذری یافته

ارزی‌سازی مدل
برای ارزی‌سازی مدل، از داده‌های به دست آمده از آزمایش‌های اختصاصی استفاده شد. سال‌های زراعی با داده‌های هویو آزمایش‌های بزرگ‌تر و به آن سال در هر آزمایش تنظیم و مدل اجرا گردید. سپس عملکردی‌های حاصل از شیب زایی توسط مدل با

\[
RMSE = \left( \frac{1}{n} \sum_{i=1}^{n} (P_i - O_i)^2 \right)^{0.5}
\]

\[
MBE = \frac{1}{n} \sum_{i=1}^{n} (P_i - O_i)
\]
MPE = \left[ \frac{\sum_{i=1}^{n} (O_i - P_i)}{O_i} \right] \times 100 \quad (17)

\[ d = \frac{\sum_{i=1}^{n} (P_i - O_i)^2}{\sum (P_i - O_{avg}) + (O_i - O_{avg})^2} \quad (18) \]

Fig 4. Relationship between simulated and observed anthesis (a) and physiological maturity (b) dates
Fig 5. Relationship between simulated and measured grain yield (a) and biomass (b)
Table 4. Comparison of the results of anthesis and physiological maturity dates; simulated grain yield and biomass by wheat potential model (WheatPot) with observed data

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Anthesis (DAP)*</th>
<th>Physiological Maturity (DAP)</th>
<th>Grain Yield (kg ha⁻¹)</th>
<th>Biomass (kg ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Simulated</td>
<td>Observed</td>
<td>Difference</td>
<td>Simulated</td>
</tr>
<tr>
<td>Ahvaz</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fong</td>
<td>88</td>
<td>83</td>
<td>5</td>
<td>128</td>
</tr>
<tr>
<td>Chamran</td>
<td>96</td>
<td>92</td>
<td>4</td>
<td>134</td>
</tr>
<tr>
<td>Star</td>
<td>103</td>
<td>102</td>
<td>1</td>
<td>137</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chamran</td>
<td>82</td>
<td>81</td>
<td>1</td>
<td>125</td>
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<tr>
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<td>93</td>
<td>89</td>
<td>4</td>
<td>137</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Chamran</td>
<td>105</td>
<td>102</td>
<td>3</td>
<td>145</td>
</tr>
<tr>
<td>Star</td>
<td>85</td>
<td>89</td>
<td>-4</td>
<td>126</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chamran</td>
<td>97</td>
<td>100</td>
<td>-3</td>
<td>138</td>
</tr>
<tr>
<td>Star</td>
<td>107</td>
<td>111</td>
<td>-4</td>
<td>145</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chamran</td>
<td>85</td>
<td>90</td>
<td>-5</td>
<td>130</td>
</tr>
<tr>
<td>Star</td>
<td>93</td>
<td>94</td>
<td>-1</td>
<td>135</td>
</tr>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Chamran</td>
<td>107</td>
<td>103</td>
<td>-4</td>
<td>139</td>
</tr>
<tr>
<td>Star</td>
<td>85</td>
<td>90</td>
<td>-5</td>
<td>130</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>RMSE</td>
<td>3.5</td>
<td></td>
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</tr>
<tr>
<td>MBE</td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>MPE</td>
<td>2.6</td>
<td></td>
<td></td>
<td>1.2</td>
</tr>
<tr>
<td>d</td>
<td>0.95</td>
<td></td>
<td></td>
<td>0.96</td>
</tr>
</tbody>
</table>

* Days After Planting
<table>
<thead>
<tr>
<th>Factor</th>
<th>Variations %</th>
<th>Change Relative to Control (kg/ha)</th>
<th>Change Relative to Control %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>-</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>Sowing Date</td>
<td>+10</td>
<td>+33</td>
<td>+1.8</td>
</tr>
<tr>
<td></td>
<td>-10</td>
<td>-457</td>
<td>-6.0</td>
</tr>
<tr>
<td>Temperature</td>
<td>+10</td>
<td>-497</td>
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</tr>
<tr>
<td></td>
<td>-10</td>
<td>+13</td>
<td>+2.8</td>
</tr>
<tr>
<td>Radiation</td>
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<td>+10.0</td>
</tr>
<tr>
<td></td>
<td>-10</td>
<td>-750</td>
<td>-10.0</td>
</tr>
</tbody>
</table>

Table 5. Analysis of model sensitivity to sowing date, temperature and solar radiation.
References


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I- Model description and evaluation

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ABSTRACT


A simple mechanistic crop growth simulation model “WheaPot” was developed for simulating site-specific wheat yield potential. The model simulates critical phenological stages and dry matter production as a function of temperature and solar radiation. Crop aspects of the model including developmental stages, dry matter production and grain yield are modulated in sub-models. The model requires inputs of site mean monthly weather data (minimum and maximum temperatures in °C) and photosynthetically active radiation (PAR in MJ m⁻²), and plant characteristics such as sowing date, required growing degree days (GDD) for vegetative and reproductive phases, radiation use efficiency (RUE in g MJ⁻¹), and harvest index (HI). The model was verified using different experiments, which were carried out in several locations in Khuzestan province in 2003-2004 and 2004-2005 growing seasons. Comparison of simulated and measured values under non-limiting conditions indicated satisfactory performance of the model in predicting anthesis and maturity dates, and a fair prediction of dry matter production and grain yield with root mean square error (RMSE), 3.5 d, 4 d, 0.65 t ha⁻¹ and 1.69 t ha⁻¹, respectively. The model proved as a useful tool for a rough estimation of wheat yield potential at regional level where there is no access to daily weather data.

Key words: Modeling, Yield potential, Wheat, Dry matter, Grain yield, Maturity.

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