Developing a Neural Network to Simplify Durum Wheat Yield Prediction in Italy

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Aim

Applying a neural network (NN) to develop a simplified model for yield forecasts in durum wheat (*Triticum turgidum* ssp. *durum*), using back-propagation algorithms based on the mechanistic model AFRCWHEAT2 (Porter, 1993; Porter et al., 1993). This would result in easier predictions thanks to a reduced number of inputs compared to those (16) needed for AFRCWHEAT2.

Materials and Methods

The AFRCWHEAT2 model was run to predict durum wheat phenology, dry biomass (BY) and grain yield (GY) in 100 site-year combinations in 6 Mediterranean sites (training set). In the same cases a NN was applied, whose training occurred through supervised learning, i.e. by comparison with the 100 examples of inputs and outputs issued by AFRCWHEAT2. Weather data were directly fed to the NN, while phenology was determined through AFRCWHEAT2, then fed to the NN. A training rate of 0.3 with a momentum of 0.2 over 5,000 iterations was adopted, together with a cross-validation technique to avoid over-fitting.

In the training phase, the NN with the best prediction ability was selected by adjusting the number of neurons in the hidden layer(s), based on the amount of explained variation (R^2) and residual error (RMSE). Thereafter, 114 different site-year combinations from the same data set were used in the validation phase, calculating the relative error (RE) of BY and GY predicted by the NN vs. the AFRCWHEAT2 model, and the coefficient of variation (CV) between them.

Results and Discussion

In the training phase, a NN with 5 neurons in a single hidden layer showed the best prediction ability (R^2 = 0.99 and 0.98, and RMSE = 59.5 and 25.3 g m^{-2} for BY and GY, respectively), and was therefore selected. In the validation phase, the trained NN determined similar BY and GY predictions as the AFRCWHEAT2 model, on average (Figure 1). However, in both traits the NN exhibited a tighter distribution of the data, as shown by the lower inter-quartile difference (vertical boxes) and the lower spread of outliers. As a result, BY and GY predictions with the two models were not sufficiently correlated (data not shown) to ensure a reliable use of the NN in substitution of AFRCWHEAT2. The average RE was negligible: -1.7% (BY) and -1.8% (GY), but RE data >20% (in absolute value) were observed in 5.3% (BY) and 22.8% (GY) of the 114 cases, indicating divergence especially in GY.

The variation between the NN and AFRCWHEAT2 is best summarized by the CV's recorded in the six sites across the Mediterranean (Table 1). A CV below 10% indicates a very good match between the two models; between 10% and 20%, fairly good match; between 20% and 30%, sufficient match; above 30%, poor match. Based on this, BY showed a tighter relationship between data issued by the two models. Conversely, GY showed a looser relationship, especially in the two sites of Greece and Morocco featuring strong inter-annual variation and occasional very low GY's with AFRCWHEAT2. Hence the selected approach, a generalized NN for the whole Mediterranean Basin, was not shown able to reproduce the inter-annual and intra-annual variability, at least compared with a mechanistic model. Based on these results, it is envisaged that NN's at a smaller scale, even within the same general environment, could better fit specific conditions.

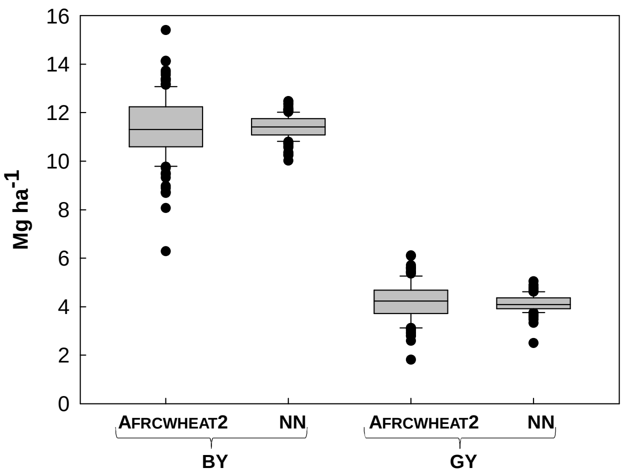

Figure 1. Box plot of biomass yield (BY) and grain yield (GY) predicted with AFRCWHEAT2 and the neural network (NN).

Table 1. Variation (CV %) in biomass yield (BY) and grain yield (GY) predicted by the NN vs. AFRCWHEAT2 in 6 Mediterranean sites (n=19).

Site	BY	GY
FR	7.7	14.1
SP	10.7	18.1
IT	10.3	15.2
GR	11.0	21.7
MA	14.2	21.1
IT2	6.9	13.5

Conclusions

The first attempt to develop a neural network to simplify yield predictions in durum wheat under warm-temperate conditions, outlines prospects for future adoption of this tool. However, further development is required, in order to achieve the accuracy needed for a large-scale use. In this respect, it is sensed that data from remote sensing, e.g. gross primary production, leaf area index and soil moisture, could be used in NN development and subsequent yield forecasts, leading to more reliable predictions. Under such circumstance, NN's could represent a real alternative to the elaborate mechanistic models currently used, in lieu of developing simplified versions of these latter.

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Porter J.R. et al.: 1993. Comparison of the wheat simulation models AFRCWHEAT2, CERES-wheat and SWHEAT for non-limiting conditions of crop growth. Field Crop Res 33, 131–157.