Journal of AgriSearch 3(1): 63-68
Peer Reviewed Quarterly

ISSN : 2348-8808 (Print), 2348-8867 (Online)
http://dx.doi.org/10.21921/jas.v3i1.4107

How to use crop growth model WOFOST for forecasting growth and yield of a crop

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ARTICLE INFO	
Received on :	28.02.2016
Accepted on :	03.03.2016
Published online :	10.03.2016

ABSTRACT

WOFOST version 7.1.3 is a computer model that simulates the growth and production of annual field crops. All the run options are operational through a graphical user interface named WOFOST Control Center version 1.8 (WCC). WCC facilitates selecting the production level, and input data sets on crop, soil, weather, crop calendar, hydrological field conditions, soil fertility parameters and the output options. The files with crop, soil and weather data are explained, as well as the run files and the output files. A general overview is given of the development and the applications of the model. Its underlying concepts are discussed briefly.

Keywords: computer model, crop data simulation, crop production, production ecology, soil data, system analysis, weather data

INTRODUCTION

WOFOST (WOrldFOodSTudies) is a simulation model for the quantitative analysis of the growth and production of annual field crops. It is a mechanistic model that explains crop growth on the basis of the underlying processes, such as photosynthesis, respiration and how these processes are influenced by environmental conditions. With WOFOST, you can calculate attainable crop production, biomass, water use, etc. for a location given knowledge about soil type, crop type, weather data and crop management factors (e.g. sowing date). WOFOST has been used by many researchers over the World and has been applied for many crops over a large range of climatic and management conditions. Moreover, WOFOST is implemented in the Crop Growth Monitoring System which is used operationally to monitor arable crops in Europe and to make crop yield forecasts for the current growing season. WOFOST originated in the framework of interdisciplinary studies on world food security and on the potential world food production by the Center for World Food Studies (CWFS) in cooperation with the Wageningen Agricultural University, Department of Theoretical Production Ecology (WAU-TPE) and the DLO-Center for Agrobiological Research and Soil Fertility (AB-DLO), Wageningen, the Netherlands. After cessation of CWFS in 1988, the DLO Winand Staring Centre (SC-DLO) has continued development of the model in co-operation with AB-DLO and WAU-TPE. Currently, the WOFOST model is maintained and further developed by Alterra in co-operation with the Plant Production Systems Group of Wageningen University (http://www.pps.wur.nl/UK) and the Agri4Cast unit of the Joint Research Centre in Italy (http://mars.jrc.it/mars/ About-us/AGRI4CAST).

Purpose of application: Crop growth monitoring with agro-meteorological data set. We can forecast the yield of different crops for any location well in advance with the help of previous crop, soil and weather data, and expected weather data of the particular location. This may help in decision making of agricultural production system in time.

Input data requirement:

1. Crop information like as :

** Crop identity : Rapeseed (Brassica napus L. ssp. oleifera (Metzg.)Sinsk.)

** CRPNAM : Brown sarson, Shalimar, Kashmir'

** Emergence

TBASEM : Lower threshold temperature for emergence [cel]

TEFFMX : Maximum effective temperature for emergence [cel]

TSUMEM : Temperature sum from sowing to emergence [cel d]

** Phenology

IDSL : Indicates whether pre-anthesis development depends on temperature (=0), daylength (=1), or both (=2)

DLO : Optimum daylength for development [hr]

DLC : Critical daylength (lower threshold) [hr]

TSUM1 : Temperature sum from emergence to anthesis [cel d]

TSUM2 : Temperature sum from anthesis to maturity [cel d]

DTSMTB : Daily increase in temp. sum as function of av. temp. [cel; cel d]

DVSEND : Development stage at harvest (= 2.0 at maturity [-])

** Initial

TDWI : Initial total crop dry weight [kg ha^{-1}]

LAIEM : Leaf area index at emergence [ha ha^{-1}]

RGRLAI : Maximum relative increase in LAI

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[ha ha^{-1} d^{-1}]

** Green area

SLATB : Specific leaf area as a function of DVS [-; ha kg^{-1}]

SPA : Specific pod area [ha kg^{-1}]

SSATB : Specific stem area [ha kg^{-1}] as function of DVS

SPAN : Life span of leaves growing at 35 Celsius [d]

TBASE : Lower threshold temp. for ageing of leaves [cel]

** Assimilation

KDIFTB : Extinction coefficient for diffuse visible light [-] as function of DVS

EFFTB : Light-use efficiency single leaf [kg ha^{-1} hr^{-1} j^{-1} m^2 s]as function of dailymean temperature

AMAXTB : Maximum leaf CO_2 assimilation-ratefunction of DVS [-; kg ha^{-1} hr^{-1}]

** Conversion of assimilates into biomass

CVL : Efficiency of conversion into leaves [kg kg^{-1}]

CVO : Efficiency of conversion into storage org. [kg kg^{-1}]

CVR : Efficiency of conversion into roots [kg kg^{-1}]

CVS : Efficiency of conversion into stems [kg kg^{-1}]

** Maintenance respiration

Q10 : Relative increase in respiration rate per 10 Cel temp. incr. [-]

RML : Rel. maintenance respiration rate leaves [kg CH_2O kg^{-1} d^{-1}]

RMO : Rel. maint. resp. rate storage organ [kg CH_2O kg-1 d^{-1}]

RMR : Rel. maint. resp. rate roots [kg CH_2O kg^{-1} d^{-1}]

RMS : Rel. maint. resp. rate stems [kg CH_2O kg^{-1} d^{-1}]

RFSETB : Red. factor for senescenceas function of DVS [-; -]

** Partitioning

FRTB : Fraction of total dry matter to roots as a function of DVS [-; kg kg^{-1}]

FLTB : Fraction of above-gr. DM to leaves as a function of DVS [-; kg kg^{-1}]

FSTB : Fraction of above-gr. DM to stems as a function of DVS [-; kg kg^{-1}]

FOTB : Fraction of above-gr. DM to stor. org. as a function of DVS[-; kg kg^{-1}]

** Death rates

PERDL : Max. rel. death rate of leaves due to water stress

RDRRTB : Rel. death rate of stems as a function of DVS [-; kg kg^{-1} d^{-1}]

RDRSTB : Rel. death rate of roots as a function of DVS [-; kg kg^{-1} d^{-1}]

** Water use

CFET : Correction factor transpiration rate [–]

DEPNR : Crop group number for soil water depletion [-]

IAIRDU : Air ducts in roots present (=1) or not (=0)

** Rooting

RDI : Initial rooting depth [cm]

RRI : Maximum daily increase in rooting depth [cm d^{-1}]

RDMCR : Maximum rooting depth [cm]

** Nutrients

** Maximum and minimum concentrations of N, P, and K in storage organs and in vegetative organs [kg kg^{-1}]

YZERO : Max. amount veg. organs at zero yield [kg ha^{-1}]

NFIX : Fraction of N-uptake from biol. fixation [kg kg^{-1}]

2. Soil information

SOLNAM : 'EC3-medium fine' (It depends onyour site information file name)

** Physical soil characteristics

** Soil water retention

SMTAB : Vol. soil moisture content as function of pF [log (cm); cm^3 cm^{-3}]

SMW : Soil moisture content at wilting point [cm^3/cm^3]

SMFCF : Soil moisture content at field capacity [cm^3/cm^3]

SM0 : Soil moisture content at saturation [cm^3/cm^3]

CRAIRC : Critical soil air content for aeration [cm^3/cm^3]

** Hydraulic conductivity

CONTAB : 10-log hydraulic conductivity as function of pF [log (cm); log (cm/day)]

K0 : Hydraulic conductivity of saturated soil [cm day^{-1}]

SOPE : Maximum percolation rate root zone[cm day^{-1}]

KSUB : Maximum percolation rate subsoil [cm day^{-1}]

** Soil workability parameters

SPADS : 1st topsoil seepage parameter deep seedbed

SPODS : 2nd topsoil seepage parameter deep seedbed

SPASS : 1st topsoil seepage parameter shallow seedbed

SPOSS : 2nd topsoil seepage parameter shallow seedbed

DEFLIM : Required moisture deficit deep seedbed

3. Weather information

Daily weather data of solar radiation, minimum temperature, maximum temperature and rainfall is required to run the program. The WOFOST model support InfoCrop format weather files with a minor alteration. Therefore we convert our daily weather data from exel format to InfoCrop format by conversion in weather master of InfoCrop and copy that converted file pasting in WOFOST weather folder. After doing required change save it.In addition to daily data of these parameters the below mentioned information's are also required.

Station name : Shalimar (It depends on your site information file name)

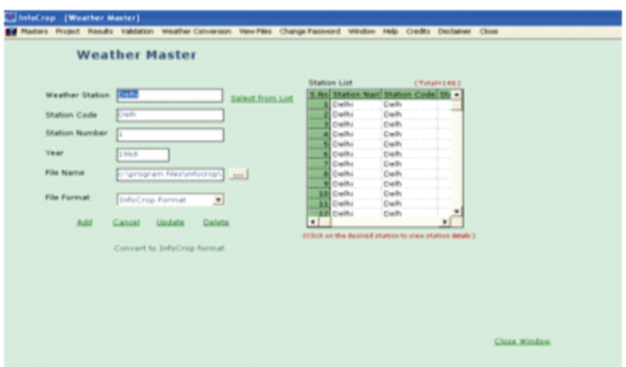
* Longitude :74 Latitude: 34 Altitude: 1587

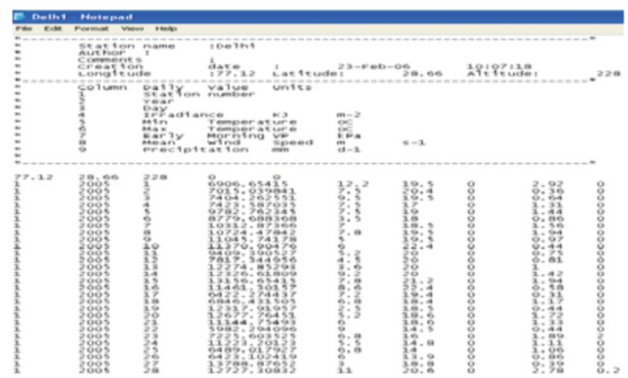
Column	Daily Value	Units
* 1	Station number	
* 2	Year	
* 3	Day	
* 4	Irradiance	KJ m^{-2}
* 5	Min Temperature	°C
* 6	Max Temperature	°C
* 7	Early Morning VP	kPa
* 8	Mean Wind Speed	m s^{-1}
* 9	Precipitation	mm d^{-1}

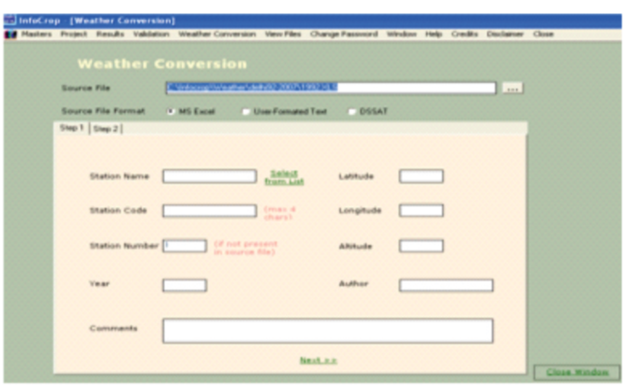
** WCCDESCRIPTION=Shalimar, Kashmir
** WCCFORMAT=2
** WCCYEARNR=2014

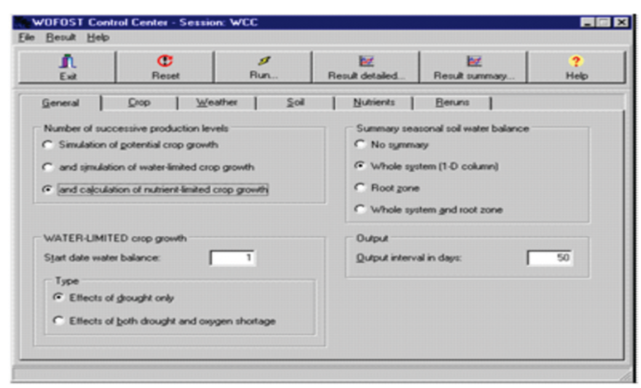
These additional information should be pasted inInfoCrop file to make it WOFOST weather file

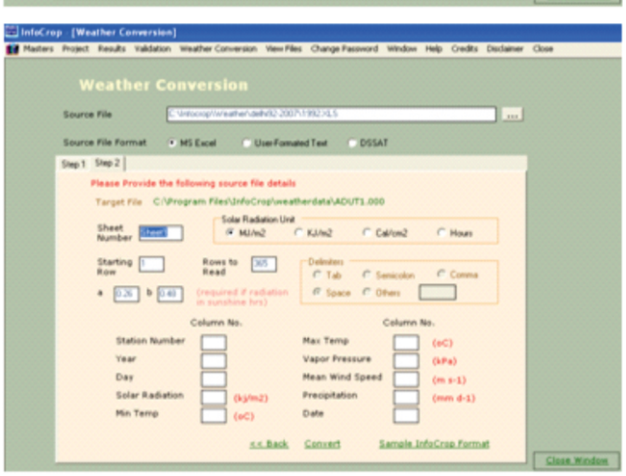
How to convert weather data from exel format to InfoCrop format

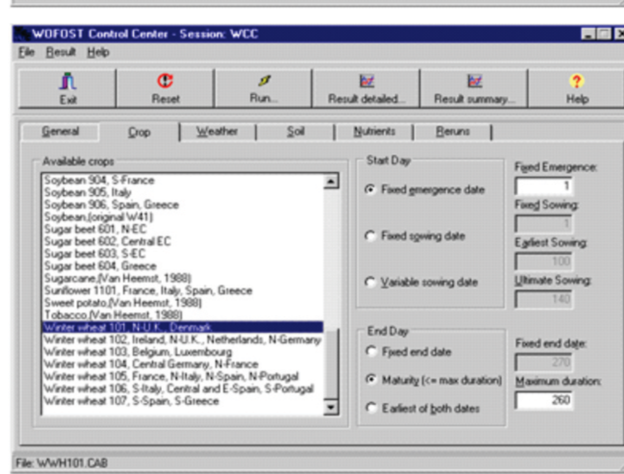


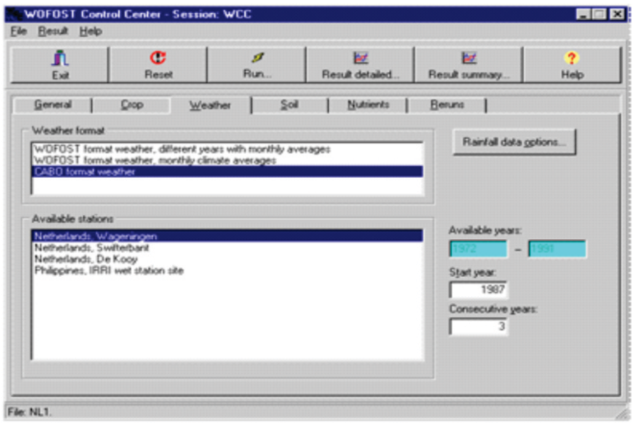


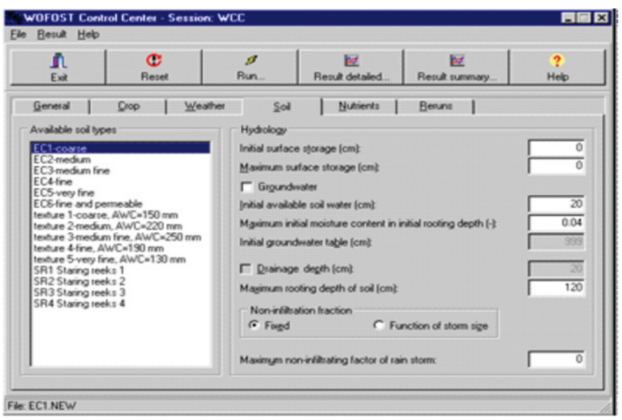


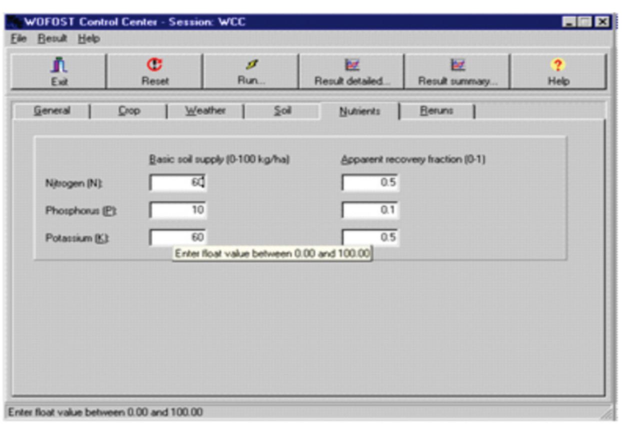


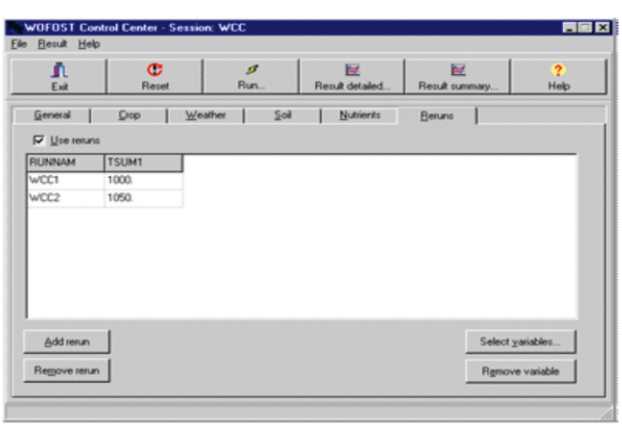


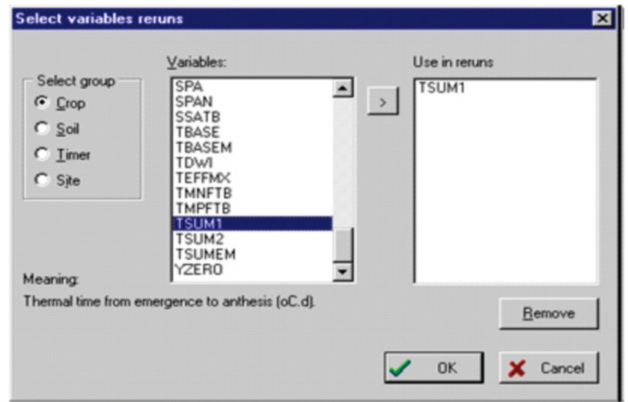


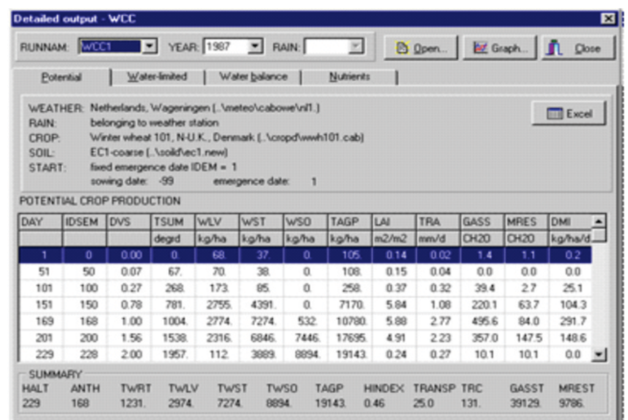












DAY	IDSEM	DVS	TSUM	WLV	WST	WSO	TAGP	LAI	TRA	GASS	MRES	DMI
			degrd	kg/ha	kg/ha	kg/ha	kg/ha	m2/m2	mm/d	CH2O	CH2O	kg/ha/d
1	0	0.00	0.	68.	37.	0.	105.	0.14	0.02	1.4	1.1	0.2
51	50	0.07	67.	70.	38.	0.	108.	0.15	0.04	0.0	0.0	0.0
101	100	0.27	268.	173.	85.	0.	258.	0.37	0.32	39.4	2.7	25.1
151	150	0.78	781.	2755.	4391.	0.	7170.	5.84	1.08	220.1	63.7	104.3
169	168	1.00	1004.	2774.	7274.	532.	10780.	5.88	2.77	495.6	84.0	291.7
201	200	1.56	1538.	2316.	6846.	7446.	17695.	4.91	2.23	357.0	147.5	148.6
229	228	2.00	1957.	112.	3889.	8894.	19143.	0.24	0.27	10.1	10.1	0.0

SUMMARY

HALT	ANTH	TWRT	TWLV	TWST	TWSO	TAGP	HINDEX	TRANSP	TRC	GASST	MREST
229	168	1231.	2974.	7274.	8894.	19143.	0.46	25.0	131.	39129.	9786.

Results for '**POTENTIAL CROP PRODUCTION**' in table format are shown for different time steps ('**DAY**') according to the value you specified in the '**Output interval in days**' in the input tab '**General**'. The results contain:

- '**IDSEM**' : number of days since emergence (d);
- '**DVS**' : development stage of crop (-);
- '**TSUM**' : thermal time since emergence (Cd);
- '**WLV**' : dry weight of living leaves ($kgha^{-1}$);
- '**WST**' : dry weight of living stems ($kgha^{-1}$);
- '**WSO**' : dry weight of living storage organs ($kgha^{-1}$);
- '**TAGP**' : total above ground production (dead and living plant organs) ($kgha^{-1}$);
- '**LAI**' : leaf area index: (leaf area)/(soil area) ($haha^{-1}$);
- '**TRA**' : transpiration rate (mmd^{-1});
- '**GASS**' : gross assimilation rate (kg (CH_2O) ha^{-1} d^{-1});
- '**MRES**' : maintenance respiration rate (kg (CH_2O) ha^{-1} d^{-1});
- '**DMI**' : rate of dry matter increase ($kgha^{-1}d^{-1}$).

A '**SUMMARY**' of results is given for the potential production:

- '**HALT**' : day number at harvest (day of the year);
- '**ANTH**' : duration of pre-anthesis phase (d);
- '**TWRT**' : total dry weight of roots (dead and living) ($kgha^{-1}$);
- '**TWLV**' : total dry weight of leaves (dead and living) ($kgha^{-1}$);
- '**TWST**' : total dry weight of stems (dead and living) ($kgha^{-1}$);
- '**TWSO**' : total dry weight of storage organs (dead and

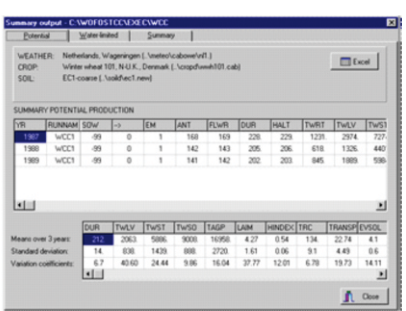
living) (kgha^{-1});

- '**TAGP**' : total above ground production (dead and living plant organs) (kgha^{-1});
- '**HINDEX**' : harvest index: weight of storage organs / weight of total above ground crop (-);
- '**TRANSP**' : total transpiration (cm water);
- '**TRC**' : transpiration coefficient rate (kg (water) / kg (dry matter));
- '**GASST**' : total gross assimilation (kg (CH_2O) ha^{-1});
- '**MREST**' : total maintenance respiration (kg (CH_2O) ha^{-1}).

The '**Graph**' button enables you to draw graphs of specified output data of the potential crop growth (Fig.). These are the same output data as shown in the table of the result tab '**Potential**'. There is also an option to present one graph showing the total above ground production (dry weight of living and dead plant organs) and its components: dry weight of living stems, dry weight of living stems and dry weight of living storage organs. The '**Graph**' window offers you to load another output file ('**Output file 2…**'). With the buttons '**Y-axis 1**' and '**Y-axis 2**' you can control the position of the y-axis (left and right).

SUMMARY POTENTIAL PRODUCTION

Summary results for potential production are given in table format. One line is given for each growing season and run. The following variables are found in the table:



- '**YR**' : simulation year;
- '**RUNNAM**' : name of the simulation run;
- '**SOW**' : sowing date (day in year) (in case of fixed emergence value is -99);
- '**-->**' : days between sowing and emergence (d) (in case of fixed emergence value is 0);
- '**EM**' : emergence date (day in year);
- '**ANT**' : duration of pre-anthesis phase (d);
- '**FLWR**' : day of flowering (day in year);
- '**DUR**' : duration of simulation period (d);
- '**HALT**' : day number at harvest (day in year);
- '**TWRT**' : total dry weight of roots (dead and living) (kgha^{-1});
- '**TWLV**' : total dry weight of leaves (dead and living) (kgha^{-1});
- '**TWST**' : total dry weight of stems (dead and living) (kgha^{-1});
- '**TWSO**' : total dry weight of storage organs (dead and living) (kgha^{-1});
- '**TAGP**' : total above ground production (dead and living plant organs) (kgha^{-1});
- '**LAIM**' : maximum leaf area index (haha^{-1});
- '**HINDEX**' : harvest index: weight of storage organs / weight of total above ground crop (-);
- '**TRC**' : transpiration coefficient rate (kg (water) / kg (dry matter));
- '**GASST**' : total gross assimilation (kg (CH_2O)ha^{-1});
- '**MREST**' : total maintenance respiration (kg (CH_2O) ha^{-1});
- '**TRANSP**' : total transpiration (cm water);
- '**EVSOL**' : total evaporation from soil surface (cm water).

A table is filled with means ('**Means over x years**'), standard deviation ('**Standard deviation**'), and variation coefficients ('**Variation coefficients**') when a run for more than two weather years is made. These statistics are given for:

- '**DUR**' : duration of simulation period (d);
- '**TWLV**' : total dry weight of leaves (dead and living) (kgha^{-1});
- '**TWST**' : total dry weight of stems (dead and living) (kgha^{-1});
- '**TWSO**' : total dry weight of storage organs (dead and living) (kgha^{-1});
- '**TAGP**' : total above ground production (dead and living plant organs) (kgha^{-1});
- '**LAIM**' : maximum leaf area index (haha^{-1});
- '**HINDEX**' : harvest index: weight of storage organs / weight of total above ground crop (-);
- '**TRC**' : transpiration coefficient rate (kg (water) / kg (dry matter));
- '**TRANSP**' : total transpiration (cm water);
- '**EVSOL**' : total evaporation from soil surface (cm water).

SUMMERY OUTPUT

The different fields in the table are (first five field are repeated in second table!):

- '**PS**' : production level (PP = potential; WP = water-limited);
- '**RUNNAM**' : name of the simulation run;
- '**IZT**' : influence of ground water (0 = no influence; 1 = influence);
- '**SOW**' : sowing date (day in year) (in case of fixed emergence value is -99);
- '**EM**' : emergence date (day in year);
- '**DUR**' : duration of simulation period (d);
- '**TWLV**' : total dry weight of leaves (dead and living) (kgha^{-1});
- '**TWST**' : total dry weight of stems (dead and living) (kgha^{-1});
- '**TWSO**' : total dry weight of storage organs (dead and

living) (kgha^{-1});

- **'var%'** : variation coefficient of total dry weight of storage organs (dead and living) (kgha^{-1});
- **'TAGP'** : total above ground production (dead and living plant organs) (kgha-1);
- **'var%'** : variation coefficient of total above ground production (dead and living plant organs) (kgha^{-1});
- **'LAIM'** : maximum leaf area index (haha^{-1});
- **'HINDEX'** : harvest index: weight of storage organs / weight of total above ground crop (-);
- **'RYLD'** : relative yield: water-limited yield / potential yield (%);
- **'RAGP'** : relative total above ground production: water-limited production / potential production (%);
- **'TRC'** : transpiration coefficient rate (kg (water) / kg (dry matter));
- **'RDMSOL'** : maximum rooting depth allowed by soil (cm).

CONCLUSION

WOFOST is a tool for the quantitative analysis of the growth and production of annual field crops. As with all tools, you should know what you could do with it and what not. Like all mathematical models of agricultural production, WOFOST is a simplification of reality. In practice, crop yield is a result of the interaction of ecological, technological and socio-economic factors. In WOFOST, only ecological factors are considered under the assumption that optimum management practices are applied.

Limitations of WOFOST

It should be stressed again that WOFOST is a model, hence a simplification of reality. The user always has to be cautious when drawing conclusions from the simulation results. Keep in mind that the quality of the model results cannot surpass the quality of the input data. A model merely elucidates the consequences of the user's opinions and data (Driessen, 1986). Therefore, the careful selection of the input data is of utmost importance. As a general rule, you should not simulate crop growth without experimentation. Experimentation is needed to obtain specific parameters and to calibrate and verify the model results.

In the validation process, crop growth as observed in reality can be compared with the simulation results. This provides an impression of the adequacy of WOFOST's predictions. When differences occur, you may need to adapt values of model-parameters (calibration). Then, the model should again be checked, against an independent set of observations. A problem in this respect is that there are an enormous number of parameters while only a few can be validated at a time. One should also realize that although calibration may improve the model results for a specific purpose, it can diminish its general applicability.

A weakness of WOFOST and all other crop growth simulation models is that some parameters are fixed whereas in practice they are known to vary, i.e. those concerning the relation between development stage and partitioning (Passioura, 1996). This problem arises when the processes at a lower integration level are insufficiently known.

REFERENCE

Driessen PM. 1986. *The collection and treatment of basic data.Introduction*. In: Van Keulen and Wolf, 1986. 203-207.

Passioura JB. 1996. *Simulation Models: Science, Snake oil, Education, or Engineering? Agronomy Journal*.**88**:690-4.

http://www.pps.wur.nl/UK

http://mars.jrc.it/mars/About-us/AGRI4CAST

Citation:

Singh L, Singh P, Kanth R H, Singh P, Akhter S and Saxena A. 2016.How to use crop growth model WOFOST for forecasting growth and yield of a crop. *Journal of AgriSearch* **3** (1):63-68