Ministry of Natural Resources of Russia
Federal Service of Hydro-Meteorology and Environment Monitoring
National Institute of Agricultural Meteorology

AGROMETEOROLOGICAL SERVICES in RUSSIA

PART II: Agromet information and services

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PART I, with Preface: “Structures and work for services and information production” can be found on the INSAM website under “New information for agrometeorologists”
PART II: Agromet information and services

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1. Forecasting
One of the principal aims of agro-meteorology is issuing some real agro-meteorological forecasts. Based on such forecasts, policy makers take decisions on producing, distributing, storing, selling or buying agricultural products. The forecast lead time is an essential value – if a user has a forecast over a longer period, this is a real advantage.

Analysis of agro-meteorological conditions is the base for evaluation and forecast for any crop. It is necessary to note that the analysis of agro-meteorological conditions in the current decade must be the real continuation of the corresponding analysis for the previous decade and it is the foundation of the analysis for the next decade.

There is a special system for issuing agro-meteorological forecasts. Different agro-meteorological forecasts distinguished by crop, topic, period, territory, etc. Below we list some agro-meteorological forecasts issued by regional agro-meteorological bodies and the Hydro-meteorological Center in Moscow:

- expected conditions of crop developing and regional mean productivity for spring and winter wheat and rye, barley, maize and other crops and grasses;
- crop wintering and crop losses;
- water storage at the end, at the beginning and during the vegetation period;
- the state of wintering crop in autumn;
- expected dates of phases and harvesting;
- agro-meteorological conditions at harvesting;
- expected dates and conditions at garden flowering;
- conditions of grass and pasture development;
- rates and dates of watering;
- recommendation on agro-technique measures including cultivating and fertilizing.

The date of issuing a specific forecast is of great importance. For example, productivity forecasts should be issued on March 1, May 20, June 20 and July 20. The wintering result forecasts must be issued on February 21 and March 11. The situation with other forecasts is similar. There is a special document “The Plan of main agro-meteorological forecasts issuing” which lists the corresponding dates.

Not all investigation proposals actually become an agro-meteorological forecast or an evaluation technique. First of all, the author must develop the corresponding procedure and test it with independent data. The obtained results are submitted to “The commission on units and techniques”. This commission carefully scrutinizes the presented materials and takes the decision: to approve (or not) the procedure and to recommend it for testing on the territory of the specific bureaus. After several years of testing, the bureaus submit to the commission the result of testing the procedure and after the investigation of presented materials the commission takes the final decision: the considered procedure can be used or not and what
is the type of that procedure – the main or additional technique. The described system works for all new units and techniques and the results are the systems of observations and services.

The base of agro-meteorological forecasts on cereals (and other crops) productivity is formed by the results of field observations conducted by fulfilling some projects in different parts of Russia. The results were clustered according to agro-meteorological zoning, crops, etc. The findings of the corresponding investigations are presented below.

Water storage (available for plants) or amount of soil moisture is very important for cereal yields. S. A. Verigo estimated the reduction of cereal yields from water storage in the soil layer of 1 meter during ear forming as give in the Table below:

<table>
<thead>
<tr>
<th>Number</th>
<th>Water storage in millimeters</th>
<th>Cereals yield (% from optimal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1 – 25</td>
<td>18</td>
</tr>
<tr>
<td>2</td>
<td>26 – 50</td>
<td>46</td>
</tr>
<tr>
<td>3</td>
<td>51 – 75</td>
<td>70</td>
</tr>
<tr>
<td>4</td>
<td>76 – 100</td>
<td>86</td>
</tr>
<tr>
<td>5</td>
<td>101 – 125</td>
<td>100</td>
</tr>
<tr>
<td>6</td>
<td>126 – 150</td>
<td>74</td>
</tr>
<tr>
<td>7</td>
<td>&gt; 150</td>
<td>68</td>
</tr>
</tbody>
</table>

The technique developed by M.S. Kulik is used for estimation of spring cereal yields reduction due to some dry periods. If the water storage in the top soil or plough layer is less than 10 millimeter, then a dry period for spring cereals begins. If the water storage in the same layer is less than 20 mm, then a drought period starts. The spring cereal yield reductions are given below (in percents).

<table>
<thead>
<tr>
<th>Number of decade</th>
<th>Type of decade</th>
<th>Dry</th>
<th>Drought</th>
</tr>
</thead>
<tbody>
<tr>
<td>Second</td>
<td>5</td>
<td>–</td>
<td></td>
</tr>
<tr>
<td>Third</td>
<td>10</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Fourth (before stem-formation)</td>
<td>30</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Fifth</td>
<td>20</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Sixth</td>
<td>10</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Seventh</td>
<td>5</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Eighth</td>
<td>5</td>
<td>–</td>
<td></td>
</tr>
<tr>
<td>Ninth</td>
<td>–</td>
<td>–</td>
<td></td>
</tr>
</tbody>
</table>

The relation of the grain number in the spring wheat ear in the period from stem-formation till milky ripeness is expressed

\[ z = 0.04 \times w + 1.23 \times y - 4.3 \]

where \( w \), the sum of water consumption; \( y \), the number of spikelets in an ear. The correlation coefficient is equal to 0.85. The relation was built by L.A. Razumova and N. B. Meschaninova.
A. V. Prozerov and K. V. Kirilicsheva developed a forecast of spring wheat yields in
the form of a function of water availability $V$

$$V = \frac{W_1 - W_2 + r}{k_1 \times \Sigma d_1 + k_2 \times \Sigma d_2} \times 100$$

where $W_1$ and $W_2$, water storages at the beginning and the end of the corresponding period;
r, the sum of the precipitation for the same period; $\Sigma d_1$, the sum of the air saturation deficit
for the period from sowing to stem-formation; $\Sigma d_2$, the same for the period from stem-
formation to wax ripeness; $k_1 = 0.45; k_2 = 0.3$.

K. V. Kirilicsheva evaluated the mean region spring wheat productivity ($y$) from the
availability of water in the period from sowing till stem-formation ($w$) for the majority of West
Siberia regions by

$$y = 0.24 \times w - 2.0$$

The correlation coefficient for this relation is equal to 0.86.

For the period from sowing till earing, the correlation is equal to 0.95 and the relation
has the form of

$$y = 0.26 \times w - 4.8$$

B. P. Ponomareva proposed for the 1000 grains weight of spring wheat in the period
of grain formation the following equation with the correlation coefficient of 0.89:

$$z = 2.46 \times N + 0.05 \times w - 14.9$$

where $z$, weight; $N$, the number of spikelets in an ear; $w$, water storage in 100 cm layer of
soil.

The earlier mentioned M. S. Kulik developed a special technique to forecast the
productivity of winter wheat in European regions on other than black soil. He used two
relations. The first one applied to the halting of vegetative growth in autumn

$$y_1 = y_a + 0.115 (f \times D - f_a \times D_a) - 3.607 (f - f_a)$$

where $y_1$, forecasted productivity; $y_a$, productivity in the year-analog; $f$, the organic fertilizer;
$D$, the number of days with the air temperature from 5 ºC to 15 ºC; $a$, index for the year-
analog.

The second relation could be applied after stem-formation and it has the form of:

$$y_2 = y_1 [1.0 - 0.01(0.471 \times s + 6.5)] + 0.15 (D - D_a) - (N - N_a)$$

where $y_2$, expected productivity; $y_1$, calculated productivity in autumn at halting of vegetative
growth; $s$, the level of canopy sparseness after wintering (%); $D$, the number of days with
moderate temperature (5 ºC – 10 ºC) after vegetative growth resumption; $N$, the yield
decrease due to nitrogen leaching resulting from soil percolation.

A forecast technique with a very long lead time (the forecast issued before winter
wheat sowing) was developed in Russia. The predictors for this type of forecast are the SST
(See Surface Temperature) at predefined regions of the Atlantic and Pacific oceans, the
indexes of ENSO (El Niño Southern Oscillation) and the values of geopotential at the height
of 500 mb in a predefined region of Kazakhstan in the summer period. This technique is used
as some pilot project to predict winter cereal productivities in autumn and in March.

There is a special procedure to estimate the productivity forecast accuracy. The
 corresponding figures vary depending on time, type, region, crop, year, etc., but in general
they lie in the interval from 80 to 95 %. This procedure works after the figures on harvest and
productivity in regions are available.

In recent years there was a big project devoted to bioclimatic potential of Russia.
Bioclimatic potential is the complex parameter depending on general productivity of soil and
taking into account climatic, soil, agro-chemical and others characteristics of a territory. The
 corresponding figures for regions of our country as well as for some Western countries were
obtained. It gives the possibility to evaluate potential crop productivity depending on
bioclimatic potential of the territory.

Not only crop productivity is the subject of forecasting. For example, A. I. Strashnaja
with her colleagues developed a procedure to estimate the date for sowing winter crops as
\[ n = 1.09 x^3 - 37.513 x^2 + 438.07 x - 1592.8 \]
where \( n \), the sowing date (the days from August 1); \( x \), the mean air temperature in the period
from August 21 till October 1. The correlation coefficient for this relation is equal to 0.79. This
relation is valid for all regions of the Central “Not Black” Area.

Similar relations could be built for other types of forecast.

We think that the presented relations give a general impression about our approaches
in agro-meteorological services. Similar techniques could be used in different regions for
other crops, varieties, periods, etc.
2. Crop state evaluation

The principal agro-meteorological estimation in the existing system of agro-
meteorological services is the assessment of observed agro-meteorological conditions and
their influence on crop growth and development. The core of corresponding evaluations is
the agro-meteorological information of remote sensing data with ground truthing.

We begin with ground data. Dates and agro-meteorological conditions in autumn
have significance for winter wheat productivity. Ill-timed sowing and unfavorable agro-
meteorological conditions in the autumn period of vegetation causes the tillering capacity of
wheat to be low, its roots to be not properly developed, the resistance to winter to be low, the
accumulated nutrients to be not enough. This all results in plant death or in number of ears
decreasing. Overdevelopment of plants also is not good for wintering because a big
underground mass requires significant resources for respiration. In general, the normal plant
at vegetation growth halting in autumn has 3 – 6 sprouts.

There are a lot of relations describing the duration of the period from sowing till
emerging. The most common is the relation suggested by V. P. Dmitrenko
\[ n = 2.1 + \frac{112}{t} + 0.0105 (W - 30)^2 \]
where \( n \), the duration in days; \( t \), mean temperature, \( W \), water storage in the topsoil at the
beginning of the period.

The period from stem-formation till earing was called "the critical one for plant
development" by P. I. Brunov. Water requirement is highest because of the intensive
vegetative growth. It was ascertained that yield was maximum if water storage (productive
water) in the top layer of 100 cm was 100 – 125 mm in the period of stem-formation till
flowering. Yield was only 70 % if the corresponding figure was 50 – 75 mm and yield was
less than 46 % if water storage decreased to 25 – 50 mm.

Water storage in the top layer of 100 cm in the period of stem-formation till flowering
is mostly determined by water storage in spring; the correlation coefficient is equal to 0.90 for
stem-formation.

The number of sprouts in spring as well as in stem-formation is a good parameter for
determining the number of stems with ears in ripeness.

In general the law of limiting factors should be used: if a particular agro-
meteorological characteristic is very often in deficit, the value of that parameter has the
strongest influence on forthcoming yield. Wheat canopies in our country are located in
regions with water deficiency or unstable moisture conditions. So water storage and the type
of precipitation have good perspectives to be important predictors in estimating the current
situation and further yield.
Interesting results were obtained by using remote sensing data for crop state evaluation. There are two approaches to apply remote sensing information in crop state estimation.

The first approach is connected with the idea that a satellite image should be calibrated. The calibration data – some information from ground observations (ground truth) and the chain of events could be imagined: ground observations and a satellite image -> the satellite image calibration (transforming of radiation flows into agro-meteorological parameters) -> evaluation on the basis of the agro-meteorological parameter concerned. That approach is used in the system of crop state estimation on the base of ground and satellite information.

The ground data: the plant density on the field. The reason: the majority of agro-meteorological stations give the corresponding figures. The satellite data: digital images from the AVHRR radiometer on board of polar orbital satellites from NOAA. The calibration: building the regression between density and vegetation index. The criteria: the canopy could be in one of three states (bad, satisfactory, good) taking into account the expected yield. The system works successfully in the European part of Russia for more then 10 years.

The second approach is based on the idea of combining satellite and ground data. Multiple regression was used to obtain the corresponding relation. For example, the valid equation on the winter wheat yield for the territory of Ulianovsk, Penza, Samara, Saratov and Orenburg regions for the second decade of May has the form

\[ Y = 38.18 \text{ NDVI} – 0.92 \text{ D} + 8.77 \]

where Y, yield; NDVI, vegetation index (derived from Terra images – MODIS unit); D, air saturation deficit.

There are a lot of relations for crop state estimation for which it is very difficult to distinguish them from the prediction relations. In our opinion, estimation is a kind of science but forecasting is close to an art, because the real forecaster uses the available equations, models and other sources of agro-meteorological and relevant information and finally gives a figure which may not be a calculated one.
3. Wintering

The cold period of the year is very dangerous for plants in the main regions of winter crop cultivation. Plants in winter are in the state of forced “outage” and they are constantly affected by meteorological factors which influence the wintering process directly as well as test the plant resistance for unfavorable conditions. We consider in short only the cardinal reasons of winter plant death.

Frost is the main reason for the death of winter crops in large areas. That death is the result of soil temperatures decreasing below a so called “critical temperature” which reflects the plant resistance to low temperature. Such decreasing temperatures at the depth of the tillering node are observed during strong frosts with a lack of (or too thin a) snow cover on the fields and therefore significant frost penetration into the ground.

Agro-meteorological conditions for killing frost could be in the first part of a winter, before formation of a sufficiently thick snow layer on the fields to protect plants from frost. Death by frost in the second part of a winter is possible only in regions with unstable snow cover in some years.

Frost damage becomes visible when cell turgors change, when colours are changing (getting brown), through maceration and tissue dying off. The level of damage depends on intensity and duration of the action of dangerous frost as well on the state of plant itself. The death of the above-ground plant parts is not the full death of the plant. The critical factor under killing frost is the level of tillering node damage.

Strong tillering node damage inevitably results in death of the whole plant. Temperatures causing tillering node death depend not only on crop type and crop variety but also on crop state in autumn and changing frost resistances under observed agro-meteorological conditions. Frost resistance decreases with thaws. An intensive and long thaw weakens the plant state and a subsequent dramatic temperature decrease could then kill much more plants than would happen with a slow decrease of temperature.

A second significant reason is asphyxiation. Asphyxiation is a very complicated process. Asphyxiation results from plants staying at temperatures near 0 ºC for a long time, without light, under a thick snow cover and with little frost penetration into the ground. Physiologists say that such conditions favour nutrition (sugar) consumption from respiration, resulting in plant exhaustion while exposed to fungus diseases. Snow mold (*Fusarium nivala*), white and gray rot, sclerotinia (*Botrytis cinerea, Sclerotinia granincaurum Elen, Sclerotium rhizoides*) are the fungus diseases most propagated under asphyxiation.

The fungus diseases develop only at favorable conditions: temperature under snow being near 0 ºC, air humidity exceeding 90 % and no light at all. The most critical factor for asphyxiation is the surface temperature under snow.
Below is the sugar consumption (in milligrams) by respiration at the different temperatures for 1 gram of dry matter for well developed and hardened off plants. The figures were obtained by I.M. Petunin, using the respiration equation and atomic weight of the corresponding components.

<table>
<thead>
<tr>
<th>Temperature (º C)</th>
<th>Sugar consumption</th>
<th>Temperature (º C)</th>
<th>Sugar consumption</th>
<th>Temperature (º C)</th>
<th>Sugar consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>9.86</td>
<td>1</td>
<td>5.74</td>
<td>-5</td>
<td>3.05</td>
</tr>
<tr>
<td>6</td>
<td>9.07</td>
<td>0</td>
<td>5.23</td>
<td>-6</td>
<td>2.66</td>
</tr>
<tr>
<td>5</td>
<td>8.30</td>
<td>-1</td>
<td>4.73</td>
<td>-7</td>
<td>2.30</td>
</tr>
<tr>
<td>4</td>
<td>7.56</td>
<td>-2</td>
<td>4.27</td>
<td>-8</td>
<td>1.97</td>
</tr>
<tr>
<td>3</td>
<td>6.91</td>
<td>-3</td>
<td>3.84</td>
<td>-9</td>
<td>1.66</td>
</tr>
<tr>
<td>2</td>
<td>6.31</td>
<td>-4</td>
<td>3.43</td>
<td>-10</td>
<td>1.37</td>
</tr>
</tbody>
</table>

Asphyxiation is a very long process and it lasts at least 80 – 100 days. Plant death will only be observed after that period. The duration of this process is significantly longer than the killing process by frost.

Other important reasons of plant death in wintering are overwetting, ice crusting, protruding and "blowing". Overwetting frequently occurs on heavy loam soil as a result of thaw water soaking in spring. Short overwetting of soil and even little soaking (5 – 10 days in autumn and winter) do not lead to plant death. Physiological processes taking place in overwetted crop require additional investigations, because reported results vary significantly.

The strongest overwetting takes place when simultaneously the following conditions hold: soil is too moist in autumn, heavy precipitation in winter, significant frost penetration into the ground and late thawing. The consequences of overwetting may be seen during all summer period. It is necessary to emphasize that overwetting is often accompanied by asphyxiation.

Opinions on the influence of an ice crust on crops are not uniform. They go form "an ice crust does not affect plants at all" to "an ice crust results in crop death". In general the truth lies between these two extreme opinions. Plant death occurs when an ice crust on the field exceeds a month duration. If the ice crust thickness is between 1.1 to 2.0 cm, the level of wheat canopy thinning is equal to 20 % or less. If the ice crust thickness lies in the interval from 4.1 to 5.0 cm, then the corresponding figure is equal to 50 %.

Protruding is the result of repeated thawing followed by frost. This process forms ice inter-layers which slightly raise the top soil with parts of plants in it. At the next thaw or air temperature increase, soil melts and it settles as a result of melting, the tillering node and some roots appearing above the surface. Then those plant parts dry, lose water and finally die due to some unfavorable conditions (frost, wind, ice crust, etc.). The described process happens on heavy unstructured soils with extreme moisture, if the duration between plowing and sowing is less then 10 – 20 days.
“Blowing” of winter crops happens very often by dust storms in the South of the country. Wind with a velocity of 10 – 12 meter per second removes soil particles which strips the tillering node and roots. If the wind velocity exceeds 15 – 20 meter per second the carried dust damages plants: it abrades or breaks and carries leaves, destroys sprouts and suckers, damages tillering nodes, etc. If the flow of particles is big enough, plants can be buried, especially in low places. These processes become more serious if fields with wintering wheat are close to upwind fallow fields.
4. Dangerous agro-meteorological phenomena

A lot of dangerous agro-meteorological phenomena, their probability, risk, damage, etc. may be discussed. However, in this chapter we give instead the values of criteria for some dangerous agro-meteorological phenomena applied to winter wheat and winter ray. This text could provide concepts for the criteria for spring wheat or soya.

Before giving the criteria we explain some conventional signs used in the text below.

\[
\Gamma TK_i = \frac{\sum_{0,1} R_{[i+(i-1)+(i-2)]}}{\sum T \geq 10^\circ C [i+(i-1)+(i-2)]}
\]

where I, the decade number; T, air temperature; R, precipitation.

\[
Md_i = \frac{\sum R_{[i+(i-1)+(i-2)]}}{\sum d_{[i+(i-1)+(i-2)]}}
\]

where d, air saturation deficit.

\[
W_{0-50}, \text{ water storage in the top layer with a thickness of 50 cm}
\]

**Period (sowing – end of vegetative growth before winter)**

**Drought in atmosphere**
\[
\Gamma TK \leq 0.19, \ Md \leq 0.09
\]

**Soil drought**
\[
W_{0-20} \leq 5 \text{ mm}
\]

**Frost**
\[
T \leq -9.0 ^\circ C - -10.0 ^\circ C \text{ at emergence}
\]

**Deficiency in heat**
\[
\sum T_{>5 ^\circ C} \leq 134 ^\circ C
\]

for the period from sowing till emergence \( \sum T_{>5 ^\circ C} \leq 67 ^\circ C \) for winter wheat, \( \sum T_{>5 ^\circ C} \leq 52 ^\circ C \) for winter ray

**Overwetting**
\[
W_{0-20} \geq 60 \text{ mm}, \ R \geq 70 \text{ mm}
\]

**Hail**

Hailstone diameter from 5 to 10 mm, duration of 10 minutes and more

**Cloudburst**

Liquid precipitation \( \geq 50 \text{ mm} \) for a period of less than 10 hours
Strong wind
The mean wind velocity \( \geq 15 \text{ meter per second} \)

Winter period

Asphyxiation
Snow layer exceeds 30 cm during 3 months and more at soil frost penetration \( \leq 50 \text{ cm} \) and \( T \leq -5 \text{ °C} \)

Killing by frost
Soil temperature at the depth of the tillering node (1 – 5 cm) \( \leq -15.0 \text{ °C} \) – -20.0 °C for winter wheat, \( \leq -18.0 \text{ °C} \) – -25.0 °C for winter ray, after a thaw \( \leq -13.0 \text{ °C} \) – -17.0 °C for winter wheat, \( \leq -15.0 \text{ °C} \) – -20.0 °C for winter ray

Period (resumption of vegetative growth after winter– stem formation)

Drought in atmosphere
\( \Gamma TK \leq 0.19, Md \leq 0.09 \)

Soil drought
\( W_{0-50} \leq 15 \text{ mm} \)

Frosts
\( T \leq -8.0 \text{ °C} \) – -9.0 °C

Deficiency in heat
\( \Sigma T_{\geq 5 \text{ °C}} \leq 70 \text{ °C} \)

Overwetting
\( W_{0-50} \geq 160 \text{ mm}, R \geq 45 \text{ mm} \)

Hail
Hailstone diameter from 5 to 10 mm, duration of 10 minutes and more

Cloudburst
Liquid precipitation \( \geq 50 \text{ mm} \) for a period of less than 12 hours

Strong wind
The mean wind velocity \( \geq 15 \text{ meter per second} \)

Period (stem-formation – earing)

Drought in atmosphere
\( \Gamma TK \leq 0.19, Md \leq 0.09 \)

Soil drought
\( W_{0-100} \leq 25 \text{ mm} \)
Frosts
\(T \leq -1.0^\circ C \sim -2.0^\circ C\) at blossoming

Deficiency in heat
\(\Sigma T_{>5^\circ C} \leq 320^\circ C\) for winter wheat, \(\Sigma T_{>5^\circ C} \leq 180^\circ C\) for winter ray

Overwetting
\(W_{0-50} \geq 230\ mm, R \geq 80\ mm, \Gamma_TK \geq 1.8\)

Hail
Hailstone diameter exceeds 10 mm, duration of 20 minutes and more

Cloudburst
Liquid precipitation \(\geq 50\ mm\) for a period of less than 12 hours

Strong wind
The mean wind velocity \(\geq 15\ meter\ per\ second\)

**Period (earing – wax ripeness)**

Drought in atmosphere
\(\Gamma_TK \leq 0.19, Md \leq 0.09\)

Soil drought
\(W_{0-100} \leq 25\ mm\)

Frosts
\(T \leq -2.0^\circ C \sim -4.0^\circ C\) at milky ripeness, \(T \leq -5.0^\circ C \sim -10.0^\circ C\) at wax ripeness

Deficiency in heat
\(\Sigma T_{>5^\circ C} \leq 480^\circ C\) for winter wheat, \(\Sigma T_{>5^\circ C} \leq 540^\circ C\) for winter ray

Overwetting
\(W_{0-50} \geq 100\ mm, R \geq 50\ mm, \Gamma_TK \geq 1.7\)

Hail
Hailstone diameter exceeds 10 mm, duration of 20 minutes and more

Cloudburst
Liquid precipitation \(\geq 40\ mm\) for a period of less than 12 hours

Strong wind
The mean wind velocity \(\geq 10\ meter\ per\ second\)

These criteria of dangerous agro-meteorological phenomena were approved by the Federal Agency and they are used in the day by day work of organizations connected to agriculture.
5. Soya

Soya is a sun loving plant and it has a significant demand for heat. Heat is most required at flowering and bean formation. Optimal temperatures for those periods are 21 °C – 22 °C. The growth and development of soya stops at temperatures below 14 °C. The requirements for heat at the beginning and end of vegetative growth are not so important. Crop could endure frost in -2 – -3.5 °C.

Soya has different requirements for water during the vegetative period. It is drought tolerant at the beginning of growth (till flowering) but deficit of water in that period decreases the productivity and prevents the lower bean formation. Water deficit at flowering, bean formation and the following stages sharply decrease soya productivity. Water consumption from flowering onwards increases very significantly due to intensive green mass development and increase of evaporating surface.

It is necessary to note a specific feature of soya: it responds negatively to dry air, especially during flowering and bean formation. Low air humidity prevents formation of new flowers and beans and makes the existing ones drop. Light is also a must for soya growth. Light deficit results in culm and butt elongation, in loss of ability to sprout and to form beans and in exfoliation of parts of the plant formed near the ground.

Soya utilizes 2 – 3 times more nutrients than cereals and that is why it grows well only on fertile and well cultivated soil. Soya requires significant amounts of fertilizers on other soils. The optimal soil for soya is deep, well drained, with a lot of phosphor, calcium, organic matter. Soil pH must be equal to 5.5 – 6.5.

Soya should be grown in succession with (in order of preference) winter wheat, maize or permanent grasses. Podded plants and sunflower are bad in this respect, due to some diseases. The majority of varieties at the stage of ripeness is resistant to lodging and their beans do not burst. This is good for harvesting.

It is necessary to emphasize that agronomic techniques for soya growth are unique for each field. Maximum productivity of a variety can only be obtained with the correct cultivation, taking into account the existing biological features, soil, weather and phyto-sanitary conditions.