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EUROPE SOYA DONAU SOJA

BEST PRACTICE MANUAL

FOR SOYA BEAN CULTIVATION IN THE DANUBE REGION

MIT UNTERSTÜTZUNG VON BUND UND EUROPÄISCHER UNION

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PREFACE

Dear soya bean producers,

Donau Soja Association is an independent international non-profit organisation with headquarters in Vienna, which gathers members from all levels of the value chain: producers, traders, processors and other organisations.

Soybean is the most important protein crop highly represented in human and animal nutrition. Each year, Europe imports about 40 million tons of soybean in the form of beans and meal while European soybean production covers only ~15% of the demand. This import dependency causes large environmental problems on a global scale, especially in exporting overseas countries. Consumer concerns about that development are rising followed by an increasing interest in a European based soybean production.

The objective of Donau Soja Association for this Best Practice Manual is to improve and increase efficiency of non-GM soybean production in the Danube region. Donau Soja developed this manual together with valuable contributions from selected agricultural experts across Europe. A remarkable output of this stakeholder process is the Donau Soja recommendation and classification system of pesticides steering towards more sustainable soybean production in the Danube region.

We are looking forward to shared success in soya bean production and we are inviting you to join us.

Best regards from Vienna,

Matthias Krön
Donau Soja Association President

1. THE IMPORTANCE AND POTENTIAL OF SOYA BEAN CROPPING IN THE DANUBE REGION

The importance of soya as a crop is based on the favourable chemical composition of the bean, which is about 40% protein and about 20% oil. Because of its high protein content, the soya bean is very important in animal feed production. Soya beans have also a high nutritional value and thus this crop is important in human nutrition. Soya proteins are rich in essential amino acids, and, in addition, the soya bean contains significant amounts of B complex vitamins, beta carotenes as well as different minerals (calcium, iron and potassium). Recently, the soya bean has been used as an important source of phytoestrogens and isoflavones.

Soya bean production is not overly demanding, which has been confirmed by numerous studies, extensive research and experiences by farmers. The soya bean is of special importance when it comes to crop rotation, due to the favourable carbon-nitrogen balance in harvest residues. In addition, soya seeds are only rarely treated by fungicides, which has a positive effect on the cost-effectiveness of production as well as on the environment. Moreover, farmers with no experience in soya bean growing will easily learn how to produce soya and will be able to effortlessly fit it into the existing crop rotation cycle. Finally, financial effects of production are not to be ignored. Bearing in mind that profitability of soya bean production starts at about 1 t/ha (which may vary over the years due to different factors), significant economic gain may be obtained by applying appropriate agricultural techniques and practices and exercising careful control of production costs.

The world's largest soya bean producers are Brazil, the USA and Argentina, while European countries only account for a few per cent of global soya production. On the other hand, Europe is a large importer of soya beans, and clearly failing to use its full production potentials. Proper introduction of soya beans in crop sequences with small grains, maize and other crops may result in long-term sustainability, self-subsistence and profitability.

1.1. The environmental impact of soya bean production

Agricultural practices have to be sustainable for nature, people, ecosystems and ecosystem services. Certainly, the maintenance of a near-natural functional biodiversity within the soil, and enhancing plant biodiversity in the agro-ecosystem, are key requirements for a resilient and sustainable agriculture. The soya bean is a legume crop. These crops cover several ecosystem services which have positive effects on soil fertility and agricultural systems as a whole (e.g. legumes have the capacity to fix nitrogen from the air, and therefore, for a successful production of soya beans, only for very few occasions small quantities of nitrogen fertilisers are needed). However, from an environmental perspective, there are some aspects to be carefully considered in soya bean production. Soya beans have a slow development at the beginning of plant growth (see chapter 2.1.). This means that soil coverage in crop establishment is not sufficient, and therefore, there is a higher soil erosion risk in the first months in soya fields. For this reason, the assessment of the soil erosion risk in soya bean cultivation has to include wider aspects: soil type, preceding crops, residue management and susceptibility of the location to erosion. Wind erosion is most likely to affect soya bean production until the beginning of flowering. During May and June, water erosion (splashing) could disperse soil particles and cause compaction or soil crusting. Winter cultivation and soil protection from October to April are needed to prevent erosion and support water conservation. Crop rotation is of greatest importance when it comes to maintaining soil fertility. The cultivation of soya beans in monocultures is not justified both from an economic standpoint and when taking the above-mentioned sustainability requirements into consideration (see chapter 2.4.). Soya bean production is easily integrated into the existing crop sequence. Soya is highly suitable for organic production as well. It easily fits into different production schemes of organic farming, from the period of conversion to certified organic farming. Due to particular requirements on organic production, and specific differences in applying synthetic pesticides and fertilisers, this handbook will deal with conventional production only, including measures which are suitable for both organic and conventional farming.

All the recommendations and technical practices concerning organic soya bean production can be found in the guideline on organic soya bean production, which will be available in 2016.

1.2. Soya bean production in the context of current European policies

The EU's Common Agricultural Policy (CAP) sets the legislative framework for farming in the EU. Danube Soya recommends to be up to date with recent direct payment requirements by contacting the local authorities. Thus, the cultivation of soya beans offers an attractive opportunity to fulfil the new CAP requirements for ecological focus areas.

With regard to environmental protection issues, other policies like the Water Framework Directive (Directive 2000/60/EC) or nature protection areas like NATURA 2000 are also very relevant. The latter fosters a European network of protection areas but does not exclude agricultural utilisation. Danube Soya recommends to contact the local authorities for further information about restrictions on agricultural practices.

1.3. Keeping soya beans free of GM contamination

In regions where GM soya is grown, conventional soya beans may become contaminated with GM soya. For farmers it is very important to put in place some preventive measures in order to ensure the economic and environmental safety of their production. With the aim of taking relevant actions and preventing GM contamination, special attention needs to be paid to critical points where such contamination is most likely to happen.

Farms that saved seed are one of the major sources of GM contamination. Certified seeds are produced under the supervision of agricultural experts and relevant state authorities and services, and they undergo multiple inspections during production, all aimed at preventing contamination. The production of farm-saved seed, however, is not strictly monitored and may turn into a significant source of GM contamination.

Even where GM contamination is below detection levels, as time goes by and the seed reproduces itself, this contamination may become a serious problem.

Another important source of GM contamination is related to soya bean harvesting. During the harvest, a certain quantity of seeds always remains in the combine. Combines which are used for harvesting GM soya beans should not be used for harvesting GM-free soya beans.

Transportation and harvesting are also critical points where soya beans may be contaminated after production. If the trailers, lorries and warehouses have not been properly cleaned, the seed left behind may be a source of contamination. This is a large problem, especially with operators and warehouses who deal with both GM-free and GM soya beans.

2. SOYA BEAN CROPPING

2.1. Soya bean growth and development

Before you decide to produce soya beans, it is very important to be familiar with the development stages and habitat requirements of this crop. When the soya plant germinates, green cotyledons ("seed leaves") are pushed to the surface. During germination and emergence, the cotyledons are open. They serve as an energy reserve for the initial development of the plant and also collect a certain quantity of light energy. Soya is considered to be germinated when the cotyledons are in a horizontal position. After the cotyledons have emerged, a pair of simple leaves develops. These leaves are opposite each other and develop above the cotyledons. All the following leaves to appear are trefoils.

The development of the soya plant can be divided into two stages. The first stage is the vegetative (V) growth stage, covering the period from emergence to the beginning of the bloom. The second stage is the reproductive (R) stage that starts with blooming and ends in maturity.

The soya bean growth and developmental stages are divided based on the development of leaves, flowers, pods and seed. Identifying soya bean developmental stages requires proper identification of nodes. A node is part of the stem connecting it to the leaf. The leaf is considered to be fully open at a given node when the edges of the blade no longer touch.

2.2. Habitat requirements

Soil

The soya plant has a strong root system and prefers well-aerated soils. For a proper development of the soya plant, the soil should be neither acidic nor saline. Lighter soils with lower water-holding capacities are not recommended for soya production. Ideally, the soil pH values are neutral (pH 6–8). The soya plant can tolerate, to a certain extent, acidic soils, but such soils mostly have very low yields. Soya bean growth and development is impossible in soils with a pH lower than 3.9 and higher than 9.6. In addition, an optimum balance of mineral substances is vital for successful soya bean production. The soya bean is usually grown in soils rich in humus, which positively affects the very structure of the soil as well as its water holding capacity. With regard to soil erosion prevention, the slope should also be considered in the choice of fields.

Temperature

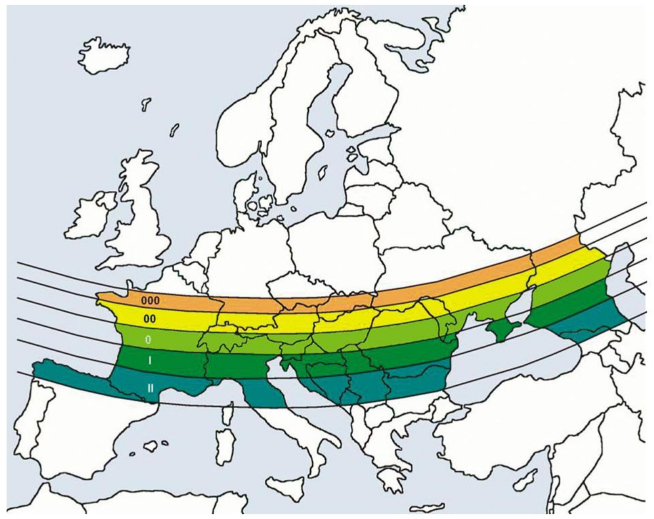
Temperature requirements depend on the developmental stage of the soya plant. At first, the biological minimum is low (emergence minimum: 7 °C). It increases as flowering draws nearer, and then slowly declines when the plant comes closer to maturity. The best description of soya plant requirements with regard to temperature is the sum of effective temperatures (sum of average daily temperatures higher than 10 °C; average daily temperatures below 10 °C are not taken into account). Depending on the maturity group, varieties have different sums of effective temperatures, from emergence to maturity: from 1000 °C for very early varieties to 1800 °C for very late ones.

Water requirements

The water requirements of the soya plant vary during the different growth and development periods of the plant. During emergence and early vegetative growth, water requirements are relatively low. The need for water reaches its maximum during the periods of flowering and seed filling, and then declines when the plants begin to mature. Total water requirements depend on the variety and maturity group: During the vegetative period maturity group 0 varieties require about 460 mm, maturity group I varieties require about 480 mm, while maturity group II varieties need about 500 mm. These values may vary ± 15% in real conditions, depending on the type of soil, the weather conditions and other factors.

Light requirements

Like all plants, the soya plant needs light in order to live. The soya plant does not only react to the amount of light, but also to daylight duration. The transition from the vegetative to the reproductive stage depends on the length of the day (photo-period). In order for the soya plant to flower it is necessary for the length of the day to be shorter than the critical photo-period. Depending on the photo-period, all soya varieties are classified into different maturity groups. For example under the conditions in the Balkan lowland (latitude 45 degrees North), maturity group I is optimal, while group 0 varieties are considered to be early varieties and group II varieties are deemed to be late ones. In addition, local factors can influence the selection of the appropriate maturity group for a given region. For instance, higher altitudes require varieties that are somewhat earlier than those of maturity group I. In order to get a rough picture of the distribution of varieties in Europe, please have a look at the maturity map of Europe.



Soya bean maturity map of Europe

000 (very early); 00–0 (early–intermediate); I (late); II (very late)

Landscape structure

Danube Soya strongly recommends to maintain an agricultural landscape which is rich in elements like hedgerows, stonewalls, terraces or in-field trees. Especially buffer strips beside fields work as an effective measure to reduce harmful erosion and its impact on the water quality of surrounding streams. Depending on the situation, domestic plants like shrubs, trees or perennial grasses are planted. The width of the buffer strips can vary but in the minimal case (grassland), a few metres are necessary. If buffer strips are implemented correctly, surface runoff and loss of nutrients can be prevented. Buffer strips and also the elements mentioned above provide structure and variation within the landscape and host protected and useful species such as pollinating bees and animals feeding on agricultural pests. Hence, farmers can also profit directly e.g. from the preservation of ladybirds, which feed on aphids.

The preservation and maintenance of such elements is a valuable contribution to biodiversity and environmental protection, and is hence subsidised by official authorities. Danube Soya recommends to contact the local authorities for further information on this issue.

Suitable varieties

Selection of the right variety is a very important task and needs to be taken seriously since it directly influences yields and the profitability of production. The maximum genetic potential of a specific variety is genetically defined and can only be achieved if all agrotechnical measures have been implemented faultlessly and if the weather conditions are ideal. Unfortunately, in real conditions, this occurs very rarely.

The following criteria have to be taken into account when selecting the variety to plant: yield quantities, stable yields, maturity group, lodging, pod shattering resistance and bean quality. Moreover, when choosing a variety it is necessary to take into account the conditions for growing this specific variety – general condition of the parcel, specific microclimate and soil fertility.

A variety may have a high yield potential in ideal conditions; however, such a high yield potential may not be fully exploited if the variety is exposed to stressful conditions. When selecting a variety, it is always essential to take into consideration the properties of this variety in a wider geographical area and over several seasons. Special attention should be paid to the properties of the variety in your region. Such an approach makes it possible to select the variety that is best suited for your parcel. Moreover, experiences by other farmers from your region should be considered, as well as your own experiences when opting for a particular variety. The maturity group or the length of vegetation also affects the yield. Generally, late varieties have a greater bearing potential when compared to early varieties. In other words, it is essential to select a variety that will reach physiological maturity just before the first autumn frosts. In addition, it is necessary to take into account instances of drought in some regions. In certain years, early varieties may give better yields than late ones since the dry period was avoided during critical stages of development.

It is always recommended to use certified seeds because of their viability and purity and absence of weeds and diseases. Farm-saved seed poses a significant risk to soya bean production.

2.3. Soya beans in crop rotation

Crop rotation is defined as a specific and well-thought-out plan for the use of production capacities in order to make the best possible use of resources.

General advantages

Well-planned crop rotation can sustain and even improve soil fertility, and also increase the yields of all crops grown in rotation. Moreover, crop rotation is very important from the standpoint of integrated pest and disease management. It aims at interrupting or disturbing the life cycles of pests and diseases, preventing the accumulation of certain crop-specific diseases, and reducing the adaptation of weeds to specific plant species grown. Proper crop rotation enables the application of smaller quantities of chemicals (fertilisers and pesticides), improves soil properties, and contributes to profitability, diversity and sustainability of agricultural production. Where applicable, cropping systems which include soya beans could also include winter cover and catch crops (mostly cereals such as rye, barley and oat) in order to improve soil protection, nutrients and water resources. This may lead to an increased number of management operations during the year, but it will benefit each crop in rotation. The soya bean is a highly suitable for crop rotation since it is a good preceding crop for most other plants. A special advantage of soya in terms of crop rotation is the lower C:N ratio of crop residues, which favourably affects soil fertility. As soya bean has similar habitat requirements as grain maize, an integration into a maize-intensive crop rotation would be beneficial.

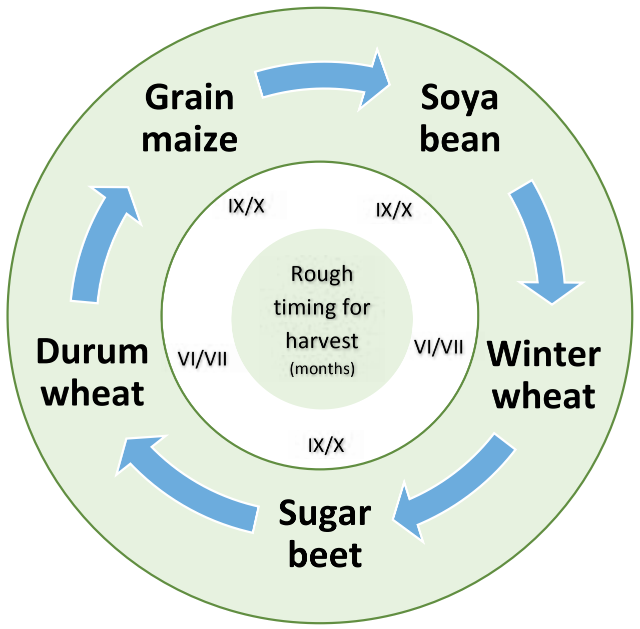
Soya bean cropping intervals

An extreme case would be the cultivation of soya bean in monocultures which is not recommended because of the higher risk of diseases, pests and weeds. Danube Soya recommends that in a crop sequence on a parcel soya should be grown with a break of minimum three years (25% of the rotation). This does not inherently exclude cultivation of soya bean after soya bean on the same field, but afterwards a sufficient break is required. This has positive effects for the nodulation of the second soya bean but requires afterwards a break of three years of cultivation of soya bean respectively hosts of common diseases (sunflower, rapeseed).

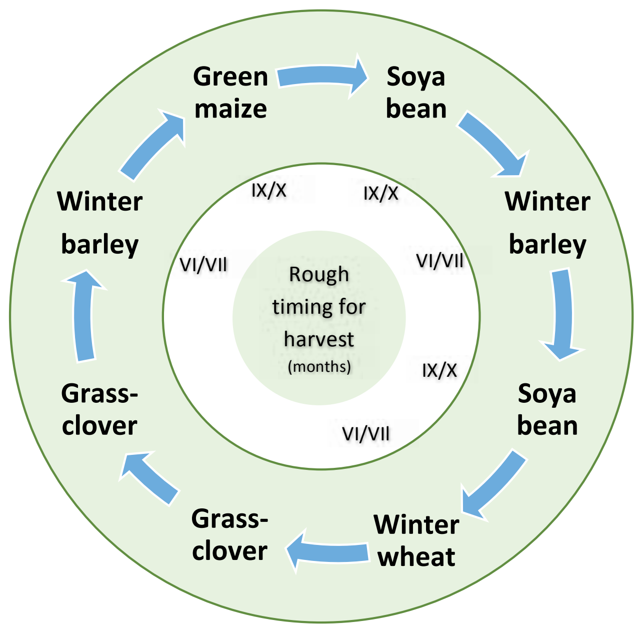
Soya bean – before and afterwards - keep in mind

Not all preceding crops are equally good for soya beans. Sunflower and rapeseed may be risky as preceding crops since they can get the same diseases as soya. Fields where the occurrence of white mould was registered are best to be avoided for the following 5 to 6 years. Generally speaking, small grains are good preceding crops for soya. They are harvested early, so there is sufficient time for the soil to rest. Maize is a good preceding crop, provided that the stalks are chopped up and ploughed under well. As for other legumes, these are not the best suited crops for preceding soya. This is not only due to common diseases, but also due to the fact that the leftover nitrogen is more useful to other crops. Another favourable practice is to plant winter cover crops (consider the restrictions for maize herbicides). As a succeeding crop after soya beans, winter cereals like winter wheat are recommendable as they could utilise the remaining nitrogen in soil. At times, a limiting factors are negative carryover effects of certain herbicides, especially soil-applied herbicides against broadleaf weeds, which could compromise soya bean production after maize. It is generally recommended to consider the herbicide recropping restrictions when planning the crop rotation. Relevant agents of such herbicides include, but are not limited to: clopyralid and nicosulfuron.

Two possible crop rotations on a parcel: Soybeans can be easily integrated into crop rotations.



Example of a divers crop rotation for a growing region in a warm climate with focus on cereals production.



Example of a divers crop rotation for a growing region in a moist climate with livestock and crop production.

2.4. Soil preparation

Primary tillage

Primary tillage plays an important role in successful soya bean production. Primary tillage systems usually differ from one region to the other, and farmers should choose the system that is most favourable for them at a given time. Primary tillage quality determines the quality of seedbed preparation, sowing, between-row cultivation and harvesting. Primary tillage for soya is to be done in autumn. In case that small cereals are the preceding crop, stubble should be ploughed into the soil at a depth of 15 cm, or heavy harrows should be pulled to a depth of 12 cm. Such practice allows for mixing crop residues with the soil and for effective elimination of later-growing weeds. Ploughing involving soil inversion is usually done in late summer or early autumn after harvest. Late harvest and large quantities of crop residues (maize) might make primary tillage more difficult. If not already done during harvesting, it is necessary to chop up maize stover. The recommended tillage depth is up to 30 cm in order to ensure that crop residues reach a ploughing depth that allows for their proper decomposition. As for lighter soils, primary tillage can also be carried out in spring. Furthermore, there are different systems for reduced soil tillage such as direct seeding into winter rye stands (see also textbox above).

Currently, with the advancement of reduced tillage techniques (machinery, fertilisers etc.), soya bean production could be conducted under conservation tillage. Applying this tillage system may result in a positive impact on the environmental components, energy savings, controlled greenhouse gas emissions, decreased erosion and reduced run-off of nutrients and pesticides. However, a conservation tillage operation needs to be carefully planned with the specialised knowledge required to minimise negative side effects and decrease crop-protection inputs (use of pesticides. To fully apply conservation tillage, farmers have to be able to successfully manage crop residues. Shallow tillage is used after crop harvest to mix the

soil with crop residues and prevent nutrient and water losses. When soya is produced under conservation tillage, seed germination is rather difficult in compacted soil, as well as in soils with many crop residues.

Seedbed preparation

Seedbed preparation quality is of great importance for successful soya bean production. The goal of seedbed preparation is to have a 5–6 cm thick layer of warm and moist soil. Preparing a uniform seedbed allows for close contact between seed and soil. This provides consistent transfer of warmth and moisture, which is necessary in order for emergence to occur at about the same time and later on also for optimum stand establishment. Moreover, quality seedbed preparation also provides uniformity in sowing depth. Seedbed preparation cannot remedy any mistakes made during primary tillage; even if the surface layer of soil is smooth, deeper layers may remain uneven. This results in difficulties in emergence, making the rooting of young plants more of a challenge.

Seedbed preparation is most often performed twice. The first time is in early spring, when the soil is dry enough to prevent sticking and compaction. The first seedbed preparation should not be performed too late, when the soil has already dried out, because this reduces both the uniformity of the seedbed layer and the moisture content. It is recommended to do seedbed preparation in as few passes as possible and by combining the implements. The second seedbed preparation has to take place just before planting. Seedbed preparation that has been carried out properly results in a layer of finely lumpy soil. The second seedbed preparation may also be used for weed elimination and the application of herbicides and mineral fertilisers.

Primary tillage and seedbed preparation should be in line with the specific requirements of the plot, the soil type, weather conditions, the available machinery, as well as other relevant factors. An important consideration for primary tillage and especially for seedbed preparation is to limit water losses from tillage. Sufficient provision of water is particularly important for soya bean emergence, which is a crucial issue for drier regions.

2.5. Inoculation

The soya bean, like other legumes, has the ability to fix nitrogen from the air. Biological nitrogen fixation is based on a symbiotic relationship between the soya plant and soil-dwelling bacteria, where the bacteria provide nitrogen to the plant, while the plant, in return, supplies the bacteria with different nutrients. The nitrogen fixation process takes place in special root organs called nodules. The nodules are globular structures located on the roots. The process of nodule forming starts with initial root development, and the nodules are active during the latter part of the plant's growth and development period. Cross-sections of physiologically active nodules reveal a red colour, which is due to the presence of a pigment called leghaemoglobin.

When discussing the capacity of the soya plant to utilise nitrogen from different sources, it is important to be familiar with the preferences of soya plants when it comes to different sources. In case the soil contains more nitrogen, the plants will opt for this source. On the one hand, high levels of nitrogen in the soil zone adversely affect the nodule forming process. On the other hand, during the first stages of plant development, when the nodules are being formed, it is vital that soil contain a certain amount of nitrogen. The forming and development of nodules take time, and if soil nitrogen levels are very low, nitrogen deficit symptoms may occur. Although soya shows a preference for mineral nitrogen over atmospheric nitrogen,

Successful inoculation is essential for yield success.

Compare nodulation of both pictures.

the source of nitrogen has no impact on yields. Successful inoculation is essential for yield success.

Parcels where no soya beans have been grown before, usually do not contain soil bacteria necessary for nodule formation, and so it is necessary to introduce them into the soil. The most efficient way to do so is by inoculating the seed. When doing this, what should be kept in mind is that inoculants are actually living organisms. Special care should be taken in order for the seed inoculation to be done properly. Storing inoculants at temperatures that are too low or too high is to be avoided. The producers' manuals and instructions are always to be observed when it comes to the application of microbiological agents. There are some general recommendations to follow in order to carry out inoculation successfully:

» **it is vital to have a good physical contact between the seeds and the microbiological agent;**
» **only the seeds to be sown should be inoculated;**
» **chlorinated tap water should be avoided when moistening the seeds before inoculation;**
» **storing inoculated seeds is not recommended;**
» **inoculants and inoculated seeds should not be exposed to direct sunlight. All actions related to seed inoculation should take place in the shadow. Short exposure to sunlight when manipulating the seeds near the planter will not cause significant adverse effects in most cases.**

Specific environmental conditions have a negative effect on the process of biological nitrogen fixation in soya plants. Among these conditions are extreme temperatures. Optimum temperatures for the nitrogen fixation process are between 15 and 26 °C. At higher or lower temperatures, nitrogen fixation and bacteria activity are reduced. High levels of soil nitrogen will also adversely affect the process of nitrogen fixation, lowering the number of nodules and reducing the activity of the bacteria. Droughts also have a negative impact on the nitrogen fixation process since the process is highly sensitive to the quantity of water. Last but not least, if there is an excess of water and the soil is too wet or flooded, the air cannot reach the root system zone, and therefore no nitrogen fixation can take place.

The question whether it is necessary to perform inoculation every year on the same parcels is also related to the costs and risks that will arise if nodulation fails. The costs of inoculation should be looked at in relation to possibly reduced yields.

2.6. Fertilisation

High yields cannot be expected in plots where some mineral elements are scarce. Before sowing soya beans, it is therefore necessary to ensure the availability of specific mineral elements in the soil. No general recommendation can be made regarding the amount of mineral fertilisers to be applied as every parcel is different. Every parcel has a different history, different levels of available mineral elements, different preceding crops, and therefore the quantity of mineral fertilisers should be adjusted to each individual field parcel. The amounts of mineral fertilisers recommended for each parcel should be based on agrochemical soil testing. On the one hand, the use of excessive quantities of mineral fertilisers is not justified both from an economic and environmental standpoint as especially nitrogen may leach to groundwater. On the other hand, quantities that are too small make top yields impossible. In parcels well provided with nutrients, the quantity of applied nutrients (in the form of mineral fertilisers or manure) should correspond to the amount of nutrients removed by the harvested crop. In case of a deficit of some elements in the soil, it is necessary to compensate for this deficit to maintain soil fertility.

Soya plants need 70–90 kg of nitrogen, 16–27 kg of P_2O_5 and 36–60 kg of K_2O for one tonne of grain and the corresponding quantity of green biomass. Harvesting removes 60 kg of nitrogen, 11–14 kg of P_2O_5 and 20–23 kg of K_2O with each tonne of beans. The remainder of nutrients is returned to the soil by ploughing under the crop residues. Repeated removal of crop residues from the parcel depletes the soil of nutrient reserves.

Removed nutrients by the harvest should be replaced in a balanced way. Therefore soil tests for the status of nutrients provide valuable information for fertilisation suggestions.

Danube Soya recommends at this point to contact the responsible authorities for local information on the properties of soils as well as for further information regarding fertilisation and soil tests.

Nitrogen

Soya has very high demands in nitrogen. Significant amounts of nitrogen can be taken from the atmosphere, provided that inoculation has been done properly. Depending on different conditions during soya bean growth and development, atmospheric nitrogen fixation can provide between 20 and 75% (usually 50–70%) of the total nitrogen requirements of soya plants. The remaining amount of nitrogen needed is supplied from the soil, through mineralisation of organic matter or nitrogen left over from the previous crop. This makes this crop additionally attractive for farmers, as fertilisation costs are low. Soya beans require mineral nitrogen during a short period of time only, until the root nodules become functional. This period begins after emergence and usually lasts for three weeks. However, stress conditions can prolong this period, delaying nodule formation and prolonging the time mineral nitrogen has to be applied. High amounts of soil nitrogen inhibit nodule formation and atmospheric nitrogen fixation.

Thus, the decision whether nitrogen fertilisation makes sense depends on the availability of nutrients in the soils as well as on the costs of application. Naturally fertile soils with good mechanical properties can provide high yields without applying mineral fertilisers. Putting these factors together, we can conclude that nitrogen fertilisation of soya beans is a rather uncommon practice in Central Europe, and not advisable here.

Phosphorus and potassium

The quantity of phosphorus and potassium fertilisers used depends on the presence of these minerals in the soil. High levels of phosphorus and potassium may have an adverse impact on the yield. The soya bean is very good at utilising phosphorus distributed throughout the entire root system zone. It is not recommended for phosphorus fertiliser to be applied in bands. In addition, the soya bean is able to use phosphorus left over from the previous crop, so it is possible to fertilise soya plants by applying phosphorus fertiliser during prior cropping periods. The potassium uptake peaks during vegetative growth and decreases with pod formation. A potassium deficit manifests itself as necrosis on the edges and tips of older leaves. It is essential to fertilise soya with potassium only in such quantities as will be removed by the harvested crop. High levels of certain elements may have an adverse impact on the yield due to antagonism between them and the transformation of nutrients into forms that cannot be used by the plants. That is why it is very important to maintain the optimum ratio of mineral elements in the soil. The quantities of mineral fertilisers used are to be determined based on agrochemical soil testing.

Microelements

In addition to nitrogen, phosphorus and potassium, other elements are also necessary for proper growth and development of soya (zinc, iron, molybdenum, manganese, boron, sulphur, etc.). Micronutrient deficits rarely occur in average and good soils. Farmers should first deal with any problems related to nitrogen, phosphorus and potassium supply, and only then turn to microelements. In lighter soils, more acidic or alkaline soils, deficits in microelements may sometimes arise. At times, even though the soil is well supplied with iron, soya plants may develop iron deficiency chlorosis. Iron deficiency chlorosis may also occur in carbonate and alkaline soils if the weather is cold and wet. It is usually a passing phenomenon with no serious consequences.

Manure

Both animal manure and green manure application are beneficial to soil fertility. Soya responds well to manure application; however, parcels where animal manure has been applied can be better utilised by growing non-legume crops. Due to the soya plant's relatively low needs for mineral nitrogen, and the suppression of nitrogen fixation in conditions with high nitrogen levels, maize and small grains may give better results in parcels where animal manure has been applied. The soya bean will make very good use of the prolonged effect of animal manure application over the following two or three years.

Manure application is one essential mean to build up or to maintain organic carbon in soil which can compensate shortages of nutrients and water for a certain time as organic compounds in soil act as storage. However, this is a finite pool and for the purpose preservation, a return of crop residues and a careful return of nutrients removed by plants are necessary. Building up organic carbon in soils is a process which can take a long time. In contrast, exploitation of organic carbon and the resulting degradation of soils can occur within only a few years of careless management.

2.7. Soya bean sowing

Planting time

The weather and other local conditions determine the date of planting. Soya planting should be started as early on as possible. The decision on when to plant should be based on the temperature of the seedbed soil and not on the calendar. Moreover, the occurrence of late spring frosts should be taken into consideration when deciding on the planting time. The optimum planting time for soya is when the seedbed layer temperature levels off at about 10 to 12 °C. Planting too early at low soil temperature will slow down emergence. The sum of effective temperatures for soya emergence is about 100 °C. In case soya has been planted too early, young plants can tolerate brief spells of frost (-4 °C). When planting several varieties from different maturity groups, the varieties with the longest vegetative period should be planted first. Planting too late may result in flowering occurring to early, which has a negative impact on the yield.

Planting rate

One of the main preconditions for achieving high yields is the optimum plant population density. In general, soya beans tolerate different planting rates. The optimum planting rates should ensure quick row closing and the optimum first pod height. Where density is lower, soya develops lateral branches and the first pod will be low. This usually causes significant harvest losses, and weed management is more difficult. On the

Maturity group	Optimum plant density (in thousands per hectare)
000	550–600
00	500–550
0	500
I	450
II	400

other hand, populations that are too dense are prone to lodging, which increases harvest losses and provides an environment that is more favourable to diseases. High yields depend not only on the optimum plant density but also on proper plant distribution. Smaller or larger gaps in the rows result in losses at harvest and make weed control more difficult.

Generally, in a specific area, earlier varieties need to be planted at higher densities than the ones maturing later. The optimum plant population depends on the variety, the planting time and other local conditions.

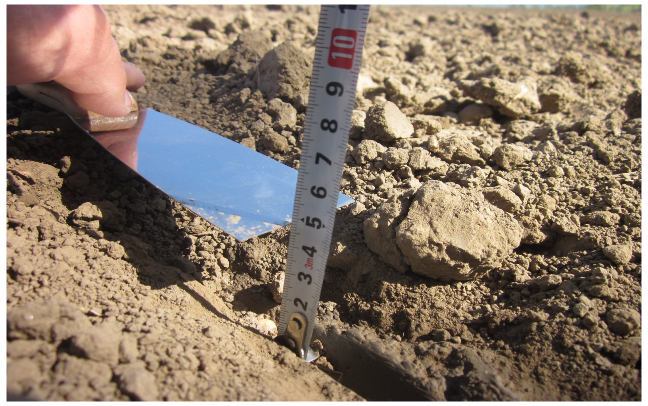
The optimum row spacing for soya beans is 45–50 cm; this provides quick row closing and optimum plant development. Wider row spacing (70 cm) is also suitable if the recommended distance between the rows cannot be achieved. However, such crops are usually less competitive in terms of weed management. On the basis of a chosen distance between the rows, the optimum plant density is achieved by calculating the distance between the plants. Pneumatic planters are recommended for soya bean planting. Given that each variety and each seed lot differ in size and germinability, it is necessary to make fine adjustments in seed spacing for each seed lot.

The distance between the plants in a row is calculated by the following formula:

$$\text{SD (cm)} = \frac{1{,}000{,}000 \ x \ UV \ (\%)}{BB \ x \ RS}$$

$$\text{UV (\%)} = \frac{Purity \ (\%) \ x \ Germinability(\%)}{100}$$

SD – Seed distance (cm)
BB – Desired number of plants (number of plants per hectare)
RS – Row spacing (cm)
UV – Utility value of seeds (%)



Before planting, the farmers should know the amount of seed required for a specific area. Due to large variations in seed size, the required amount of seed may vary significantly. For instance, the quantity of seeds needed can range from 60 kg (500,000 seeds x 120 g) to 100 kg (500,000 seeds x 200 g). Each seed package has a label containing information on germinability (which might vary between 70-98%) and the weight of 1000 seeds, so the quantity of seeds needed can be easily determined. In certain cases it might be advisable to consider a germanibility test of e.g. 50 or 100 grains.

Planting depth

Planting depth is important for achieving uniform emergence and the desired population. If the seeds are placed too deep and, in particular, if the soil is still cold, germination will be slow and emergence will be sluggish or will not happen at all. Planting too shallow is associated with the risk of topsoil drying, which may lead to a halt in germination. The optimum planting depth is 4–5 cm, or slightly less in case of heavy soils. If the soil is dry, planting should not be deeper. It is very important to provide a uniform planting depth; this will allow for uniformity in emergence as well and, ultimately, result in uniform crop maturation.

2.8. Crop cultivation

Provided that all the previous operations have been carried out properly, the soya crop is now uniform and has achieved the optimum plant population. The next step now is inter-row cultivation as a simple and very useful operation. Cultivation between the rows pursues multiple objectives: weed control and improvement of the plants' general conditions. This is especially important for crops planted at wider between-row distances and when herbicides have been applied in bands. Inter-row cultivation does not provide mechanical control of weeds growing within a row, but it is highly effective against weeds growing between rows. In addition, it breaks the soil crust, reduces soil moisture losses and improves soil aeration. The loose top layer reduces water evaporation from deeper soil layers, which results in better water retention. Inter-row cultivation also aerates the soil, which is important for fixing atmospheric nitrogen as well as for the activity of other soil microorganisms that decompose organic matter.

Two inter-row cultivations are recommended, the first one when the soya plant develops a trifoliate leaf and the second one immediately prior to row closing. During the first cultivation, cultivation may be carried out closer to the rows, while in the second cultivation narrower passes are recommended. This is important for the prevention of root damage. The depth of cultivation has to be uniform, between 3 and 10 cm, and there should always be a buffer zone (at a distance of about 15 cm from the plants).

2.9. Crop damage – replanting decision

During the vegetative season, various kinds of crop damage may occur. Herbicides, wild animals and hail are among the most common causes of crop damage. Hail often causes the most severe damage. If hail damage occurs early on, during the vegetative stage, and the soya plants are injured below the cotyledons, no regeneration of such plants is possible. The cotyledon node is the lowest point from which the regeneration of soya plants can start. Regeneration leads to the formation of lateral branches, usually at the lowest undamaged node. Crops that suffered hail damage and regenerated later, usually need more time to mature than undamaged crops. Leaf damage in young plants usually has no effect on the yield. However, if hail damage occurs in later vegetative stages or during the reproductive period, lower or higher yield losses can be expected.

Making a decision on replanting is a highly sensitive issue and requires a careful approach as well as taking into account both agronomic and economic factors. The most significant consequence of hail damage is a smaller number of plants per unit area. It easy to calculate the loss in the number of plants and the reduction in plant population: Count the total number of plants (alive and dead) in a row for a length of 5 m, and then count only the number of living plants for the same length of the row. This procedure is then to be repeated at several locations in the parcel. Based on the numbers obtained, the reduction in the number of soya plants can be calculated, and the new plant stand can be determined. Usually, if the plant population is below 200,000 per hectare, it is advisable to replant. However, this decision has to be made with great caution, taking into account also other agronomic and economic factors: herbicides applied, weather and soil conditions, seed availability and price, late planting usually resulting in lower yields, time needed for the new crop to mature and presence of weeds. In addition, all the relevant costs should be considered before making the final decision on replanting. In case the plants have suffered damage but the decision is not to replant, every effort should be made to help the damaged plants regenerate to the greatest extent possible. Inter-row cultivation is highly beneficial for plant regeneration. If herbicides have not been applied yet, postpone their application to the damaged crop as long as possible.

2.10. Irrigation

The soya plant does not have uniform water requirements throughout the entire vegetative period. A relatively small quantity of water is needed for emergence and the early growth of young plants. Water needs increase over the course of the vegetative season, reaching their maximum in the time between bloom and seed filling. The optimum soil moisture content during flowering allows the formation of a large number of pods. If drought occurs after this period, the already formed pods may be dropped, seed filling may be poorer, and the plants will probably ripen too early. When discussing irrigation, it is vital to take into account water requirements at specific developmental stages as well as weather conditions. Irrigation usually starts at the time of flowering of the soya plants and lasts until grain filling is complete. The irrigation regime should be adjusted to rainfall, the most reliable indicator for soya bean irrigation being soil moisture. The irrigation regime should be flexible enough to respond to different weather conditions and to ensure the optimum water quantity in critical developmental stages.

Irrigation strategy: After emergence and during early vegetative development, the soil moisture levels should be maintained at 50% of the soil water holding capacity. Such conditions stimulate intensive growth of the root system and prevent excessive growth of vegetative biomass. During flowering and seed filling, the soil moisture levels should be maintained at 60–70% of the soil water holding capacity. This is the most sensitive period for yield formation, so drought in this period may cause significant yield losses. Once the seed filing period is over, water requirements decrease and the plants release excessive water during maturation. In most instances, two or three irrigation cycles are sufficient, while in extremely dry years more cycles may be needed.

2.11. Soya bean as a second crop

Early soya varieties allow growing soya as a second crop. Soya can be grown after vegetable crops, peas and small grains. After harvesting the first or main crop, soya planting should be done as soon as possible. Varieties belonging to the maturity groups 00 and 000 should be planted. Planting carried out during June and at the beginning of July gives enough time for the maturation of early varieties. Although effective temperatures are sufficient in this period, water deficit may cause problems. Actually, the production of soya beans as a second crop without an irrigation system is highly risky. The irrigation schedule for the second planting should be modified since soya requires less water (one third less). The first watering should take place before or after planting in order to ensure uniform emergence. Usually, irrigation is required every 6 to 10 days, applying 5 mm per day. In case of more than 5 mm of rain per day during the irrigation cycle, this quantity should be taken into account, postponing the next irrigation cycle.

Rapid planting after harvesting the prior crop combined with reducing water transpiration due to reduced tillage are essential.

2.12. Scouting of soya bean fields and keeping of records

Regular and planned scouting as well as visiting parcels on which soya plants are grown are necessary for a timely response to any problems that may arise in soya production. During the vegetative stage, different operations take place in the parcels and visits are frequent. However, after row closing, it is also necessary to visit the crops regularly. Regular scouting enables a timely response in case a specific problem occurs. One visit per week is usually sufficient to recognise problems and decide whether action needs to be taken. After storms or other unfavourable weather conditions, scouting should be performed more frequently.

Keeping records of all the operations performed during soya bean production is a long-term measure allowing to fine-tune agronomic practices and control costs. Each individual field has its own specific characteristics, and the fine tuning of agricultural practices for each parcel results in optimum practices, which is a precondition for positive financial results. Production costs and prices for offtakers vary from year to year, so by optimising the agronomic practices and controlling the costs, maximum profits can be achieved. It is advisable to keep records for each individual field, from the time and method of primary tillage to herbicides applied to harvesting and yields. In addition, it is useful to record all the costs related to soya bean production.

Time	Purpose
Prior to planting	Weeds
Emergence	Effectiveness of pre-em herbicides Emergence and plant population achieved Weeds, post-em herbicides
Vegetative growth and row closing	Effectiveness of post-em herbicides Inter-row cultivation
Flowering, pod formation and seed filling	Diseases and pests Any additional protection and control measures General crop condition
Harvesting	Harvesting time Weed population

3. INTEGRATED WEED MANAGEMENT (IWM)

3.1. The importance of weeds and Integrated Weed Management in soya bean production

Integrated Weed Management is an approach to managing weeds more sustainably by combining biological, cultural, physical and chemical tools in a way that minimises economic, health and environmental risks.

Dominant broadleaf weeds in soya bean fields include, but are not limited to: *Ambrosia artemisiifolia, Cirsium arvense, Amaranthus* spp., *Solanum nigrum, Chenopodium album, Chenopodium hybridum, Sinapis arvensis, Datura stramonium, Xanthium strumarium, Abutilon theophrasti, Convolvulus arvensis, Polygonum* spp., *Stachys annua, Sonchus arvensis, Calystegia sepium* and *Hibiscus trionum*. The grasses *Echinochloa crus-galli, Sorghum halepense, Setaria* spp., *Digitaria sanguinalis* and *Panicum* spp. are among the most widespread weed species.

Crop rotation, timely and high-quality soil tillage, seedbed preparation and other measures that provide optimal conditions for the growth of soya bean plants are preconditions for successful weed management. In addition to the above measures, particular attention should be paid to the proper selection and application of herbicides.

3.2. Competition between weeds and soya beans

The soya bean is susceptible to the presence of weeds in early stages of growth, and careful weed management is crucial to allow the soya bean to overcome the competition from weeds. If weeds are kept below threshold levels for the first 6 weeks after planting, soya beans can usually compete well with the weeds that emerge later in the season. Besides the negative direct impact of weeds on the growth of soya beans early in the season, later emerged weeds greatly interfere with harvesting and indirectly may result in yield loss and reduced seed quality. Reducing soya bean row spacing can delay the beginning of the critical period by reducing the competitiveness of weeds. Weed control based only on a single post-emergence herbicide application is associated with the highest risk because of the difficulty of determining the optimal timing of weed removal (beginning of a critical weed-free period).

3.3. Scouting of fields and planning of integrated measures

Proper weed identification and measures while the weeds are small are the keys to successful weed management. To ensure efficient weed management, appropriate measures should be planned and recorded for each field. The primary problem weeds should be identified, recorded and mapped for each planting area. Monitor and keep record of IWM effectiveness and, in case of ineffective IWM practices, take corrective measures. A well-planned integrated weed control programme involving field analysis and a combination of cultural, mechanical and chemical control practices is the best approach.

3.4. Preventive weed control measures

Practise prevention and avoid introducing new weed species. Where possible, prevent the introduction of weed seed into inputs such as crop seed, machinery, manure, etc. Control weeds in the field before they set seeds, and control weeds in the periphery of the field to prevent the introduction of weed seeds into the field *(see pictures on next page)*.

SOME IMPORTANT WEEDS IN SOYA BEAN PRODUCTION

Ambrosia artemisiifolia

Sorghum halepense

Abutilon theophrasti

Solanum nigrum

Chenopodium album

Datura stramonium

Xanthium strumarium

Cirsium arvense

3.5. Direct weed control measures

3.5.1. Non-chemical weed control

The control of weeds before planting the crop is of fundamental importance. This is usually achieved by mechanical measures taken before and during seedbed preparation. In addition to applying herbicides, mechanical measure which are commonly used in organic farming are quite successful.

Flex-tine cultivators or flex-tine harrows, have flexible teeth that provide weed control by vibration. The tension can be adjusted individually or collectively, depending on the model, allowing to choose the intensity of the treatment. Cultivation depth is adjusted by wheels on the harrow or by the tractor's hydraulic system. Pre-emergence cultivation is selective because the crop seeds are planted more deeply than the weed seeds or are larger than the weed seeds, and are therefore not affected. The short-term effect of this machine depends on the growth stage of the weeds. This is a gentle measure which efficiently controls the weeds from the stages of „white thread", up to stage of two leaves of broadleaf weeds, and until the first leaf stage of grass weeds. Post-emergence broadcast cultivation can be done with a rotary hoe, which was developed to break soil crusts. This treatment is selective because the crop is better rooted than the weeds. Since the soya bean has larger seeds it establishes faster than the weeds. Rotary hoes work well against weeds that have germinated

Blind cultivation with a flex-tine harrow

Weed control in soya beans with a flex-tine harrow (left: untreated, right: treated)

Optimum "white thread" weed seedlings

Optimum conditions: dry soil, absence of crop residues, clean tines

Rotary hoes can be operated at high speeds

Inter-row cultivation is a very effective weed control method

but have not emerged or weeds with a maximum of two developed leaves. In this case, rotary hoes can be operated at high speeds (10-20 km/h), but tine-flex harrows are pulled slowly (6-8 km/h) to avoid crop injury.

The effectiveness of cultivation is directly influenced by cultivation depth and the degree of soil moisture. Cultivation that is too shallow may spare weeds and cultivation that is too deep increases the risk of crop damage. Working depth can be adjusted by means of wheels attached to the frame or the three-point hitch. Cultivating when the soil is too wet leads to clod formation and soil compaction, and may not destroy weeds. Cultivation is not only effective in weed control; it also benefits the crop by breaking up the surface crust, aerating the soil, stimulating the activity of the soil microflora, reducing the evaporation of soil moisture and facilitating the infiltration of rainwater. Cultivator selection is only one component of an effective weed control programme. Delaying treatment for a few days may significantly reduce the effectiveness of a cultivation operation, and the timing of treatment is probably more critical in successful weed control than the choice of the cultivator.

3.5.2. Chemical weed control

Substances used for chemical weed control often influence soil fertility as the beneficial organisms in the soil (earthworms, bacteria…) are also affected, with their fitness being impaired. In addition, pesticides can contaminate groundwater and can accumulate in the soil. Chemical weed control, as any other pesticide use, should be assessed carefully. Farmers should also take into account the costs of buying pesticides as well as adverse effects on their own health.

The success of soya bean production often depends on efficient weed control. The major focus should be on mechanical weed control. Only if mechanical measures are unsuccessful, chemical weed control can be recommended. Efficient chemical weed control usually depends on selecting suitable herbicides and applying them at the appropriate time. The selection of herbicides is mainly determined by the weeds present among the previous crops, the knowledge of the herbicides' spectra of activity, the herbicides' prices, the soil properties, the weather conditions, the information given by advisors and manufacturers of herbicides, etc.

Herbicides can be applied before sowing with shallow incorporation, or after sowing, pre-emergence or post-emergence of soya beans and weeds. Herbicides applied prior to sowing and incorporating are commonly used in arid regions given the fact that the operation does not require rainfall – in contrast

to herbicides that are applied after planting and before the emergence of soya beans and weeds. The range of residual herbicides available for pre-emergence application in soya beans allows you to determine the most appropriate weed control strategy, depending on the infestation that is to be expected based on the weed species and problems encountered in previous years.

The practice of pre-emergence weed control is of increasing importance. The main reason that led to the use of this strategy is the appearance of populations of *Amaranthus retroflexus*, which are resistant to ALS-inhibiting herbicides. Other reasons include changes in the weed flora, the spread of some invasive weeds (mainly *Ambrosia artemisiifolia*) as well as weeds that are difficult to control with post-emergence herbicides *(e.g. Chenopodium album).*

Adequate selection and application of pre-emergence herbicides in favourable conditions ensure maximum efficiency, permitting undisturbed growth of soya beans without competition in the first 4–6 weeks. The efficiency of such soil-applied herbicides depends on the weeds present, the types and characteristics of the herbicides used, the application rates, the mechanical composition of the soil (contents of organic matter, clay, silt and sand), the amount and distribution of rainfall, the quality of soil tillage, the presence of crop residues, etc.

Table 1: Relative efficacy of selected herbicides in controlling annual weeds in soya beans under Pannonian climate conditions.
Evaluations were carried out in Serbia. Look for approved pesticides per country in Appendix I. Red labelled substances are excluded from this and following tables.

Herbicide	Product rate	Application time	Annual broadleaf weeds										Grass weeds			Selectivity towards soya beans
			ABUTH	AMBEL	AMARE AMAHY	CHEAL	CHEHY	DATST	POLLA POLPE	SOLNI	SINAR	XANST	SORHA	ECHCG	SETSS	
Clomazone (360 g/L)	0.5 L/ha	PPI, PRE-EM	+ +	+	+	+ +	+ +	+ +		+	+ (+)	-	+ +	+ +	+ +	+ + +
Clomazone (360g/L) + metribuzin (600 g/L)	0.4–0.5 + 0.35–0.4 L/ha	PRE-EM	+ +	+ +	+ + +	+ + +	+ + +	+ + +	+ + +	+	+ + +	+	+ +	+ +	+ +	+ +
Dimethenamid-P (720 g/L)	1.2–1.4 L/ha	PRE-EM	-	+	+ + +	+ (+)	+ + +	+	+ + +	+ +	+ (+)	-	++(+)	+ + +	+ + +	+ +
Dimethenamid-P (720 g/L) + metribuzin (600 g/L)	1.2–1.4 L/ha + 0.35–0.4 L/ha	PRE-EM	+	++(+)	+ + +	+ + +	+ + +	+ + +	+ + +	+ +	+ + +	-	++(+)	+ + +	+ + +	+ +
Dimethenamid-P (212,5 g/L) + pendimethalin (250 g/L)	3.5–4 L/ha	PRE-EM	+	+ +	+ + +	+ + +	+ + +	+ +	+ + +	+ +	+ + +	-	+ + +	+ + +	+ + +	+ (+)
Metribuzin (600 g/L)	0.35–0.5 L/ha	PRE-EM	+	+ (+)	+ + +	+ + +	+ + +	+ + +	+ + +	-	+ + +	-	-	-	-	+ +
Metobromuron (500 g/L)	3 L/ha	PRE-EM	+ +	+ +	+ +	+ + +	+ + +	+ +	+ + +	+ +	+ + +	-	-	+	+	+ +
s-metolachlor (960 g/L)	1.4–1.5 L/ha	PRE-EM	-	-	+ + +	+	+ + +	+	+ +	+ +	+	-	+ +	+ + +	+ + +	+ + +
Bentazon (480 g/L)	2 L/ha	POST-EM	+ +	+	+ +	+ (+)	+ +	+ + +	+ +	+ / -	+ +	+	-	-	-	+ +
Bentazon + imazamox (480 g/L + 22.4 g/L)	1.8 L/ha (or 2 x 0.9L/ha) + 1 L/ha adjuvant Dash	POST-EM	+ + +	+ +	+ + +	++(+)	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +	+ +	+ +	+	+ +
Imazamox (40 g/L)	1–1.2 L/ha	POST-EM	+ + +	+ +	+ + +	++(+)	+ +	+ + +	+ + +	+ + +	+ + +	+ + +	+ +	+ +	+ +	+ +
Thifensulfuron-methyl (750 g/kg)	8 g/ha + 0.1% nonionic surfactant	POST-EM	+ (+)	-	+ + +	+ + +	+ + +	+	+ +	-	+ + +	-	-	-	-	+

NOTE: Based on adequate moisture, good growing conditions and proper herbicide application. For the herbicides listed above, one product trade name and formulation is provided for each active ingredient as an example. In some cases, there are other products available with the same active ingredient. Relative efficacy may differ with variations in weed size, temperature, rainfall and soil moisture.
ABUTH – *Abutilon theophrasti*, AMBEL – *Ambrosia artemisiifolia*, AMARE – *Amaranthus retroflexus*, AMAHY – *Amaranthus hybridus*, CHEAL – *Chenopodium album*, CHEHY – *Chenopodium hybridum*, DATST – *Datura stramonium*, POLLA – *Polygonum lapathifolium*, POLPE – *Polygonum persicaria*, SOLNI – *Solanum nigrum*, SINAR – *Sinapis arvensis*, XANST – *Xanthium strumarium*, SORHA – *Sorghum halepense* (from seed), ECHCG – *Echinochloa crus-galli*, SETSS – *Setaria* spp., PPI – preplant incorporated, PRE-EM – pre-emergence, POST-EM – post-emergence,
Efficacy: +++ very good to excellent (> 90%), ++ satisfactory (75–90%), + suppression only (50–75%), - not efficient (< 50%)
Selectivity towards soya bean: +++ excellent, ++ very good, + satisfactory

Table 2: Herbicides for post-emergence control of selected grass weeds with relative efficacy rating

Herbicide	Product rate (L/ha)	*Echinochloa crus-galli*	*Digitaria sanguinalis*	*Setaria* spp.	*Sorghum halepense* (from seed)	*Sorghum halepense* (from rhizome)
Propaquizafop (100 g/L)	0.8–1	+ + +	+ + +	+ + +	+ + +	+ + +
Cycloxydim (100 g/L)	1–2	+ + +	+ + +	+ + +	+ + +	+ + +
Fenoxaprop-P-ethyl (75 g/L)	1–2	+ + +	+ + +	+ + +	+ + +	+ + (+)
Clethodim (120 g/L)	0.8–1.2	+ + +	+ + +	+ + +	+ + +	+ + +
Quizalofop-P-ethyl (50 g/L)	0.5–2	+ + +	+ + +	+ + +	+ + +	+ + +

Efficacy: +++ very good to excellent (> 90%), ++ satisfactory (75–90%)

After sowing and before soya bean emergence it is recommended to use one of the following herbicide mixtures: dimethenamid-P + metribuzin, pendimethalin + dimethenamid-P, s-metolachlor + metribuzin, etc.

Herbicides and their combinations designed for applying after planting and before soya bean emergence are more effective in controlling weeds that have small seeds (less than 2.5 mm) and can therefore emerge from a shallow topsoil. This method of weed control is justified if the annual grass weeds (*Sorghum halepense* from seeds, *Echinochloa crus-galli*, *Setaria* spp., *Digitaria sanguinalis*, *Panicum* spp.) have a weak to moderate presence, whereas the annual small-seeded broadleaf weeds can be larger in number (*Chenopodium* spp., *Amaranthus* spp., *Solanum nigrum*, etc.). Some large-seeded weeds such as *Xanthium strumarium*, *Abutilon theophrasti* and volunteer or wild sunflower are more weakly controlled by the use of some soil herbicides and their application is justified in the absence of these species.
Large-seeded weeds emerge from deeper layers of the soil and applying soil herbicides on them is not effective enough even if the amount and distribution of rainfall after their application are optimal. In addition, these herbicides are not effective in fully protecting soya beans in case of high abundance of annual grass weeds (especially seedlings of *Sorghum halepense*) and perennial broadleaf and grass weeds. In these cases, it is necessary to use post-emergence herbicides in combination with inter-row cultivation.

Perennial broadleaf weeds (such as *Cirsium arvense*, *Sonchus arvensis* and *Convolvulus arvensis*) need to be controlled in previous crops (e.g. corn or stubble).

The efficacy of post-emergence herbicide application mainly depends on the weed species, the growth stage, the herbicides' properties and the amount applied, the time and uniformity of application, the herbicides' retention time on the leaves and the length of a rain-free period following the application, the relative air humidity and air temperature, the herbicide tank-mix partner as well as the application of wetting agents, fertilisers and other additives.

Weeds should be controlled in the early, and also the most sensitive, stages of growth for achieving maximum herbicides efficacy. In regard to that, delay time of application of post-emergent herbicides is very risky. If the early herbicides application does not achieve satisfactory efficacy, enough time for subsequent use of mechanical weed control measures or herbicides remains. In case of unsatisfactory weed control due to late single herbicide application, there is no possibility to prevent yield losses.

Post-emergence herbicide application from the first to the third trifoliate leaf stage of the soya beans most often minimises yield loss while maximising weed control. In order to achieve effective control of a number of weed species, it is necessary to apply a mixture of two or more herbicides.

Large-seeded weeds (volunteer sunflower, *X. strumarium*, *A. theophrasti*, etc.) that are not developed further than the first pair of true leaves stage can be effectively controlled by appropriately selected herbicides and their timely post-emergence application.

If *X. strumarium dominates,* products based on imazamox, imazamox + bentazon may be helpful.

If you opt for post-emergence weed control (it is recommended to combine it with pre-emergent herbicides), for efficient control of *Ch. album,* include thifensulfuron-methyl-based products, preferably in combination. If the thifensulfuron-methyl-based products are applied in combination with imazamox-based products, it is recommended to reduce the amount of both products because of synergism. If no efficient pre-emergent herbicides have been previously applied and if there is a need for additional measures to control *S. nigrum* and *D. stramonium*, you should preferably include a short-residual imazamox herbicide in the combination.

By the timely application of adequate selected combinations of post-emergent herbicides, annual broadleaf weeds can usually be effectively controlled and the growth of some perennial weeds (*C. arvense, C. arvensis*, etc.) can be temporally suppressed.

For maximum efficacy, the optimal time for the application of post-emergent herbicides is when the majority of weeds is in the growth stages from cotyledons to 4 leaves (*A. artemisiifolia*: maximum of 2 leaves).

If grass weeds are present in large numbers, it is necessary to apply a specific graminicide for their control. Soya bean is very suitable for the control of annual and perennial grass weeds after emergence (e.g. *S. halepense* from rhizome), and this benefit should be used if the control of these weeds in the following crops is difficult.

Herbicides applied post-emergence for the control of broadleaf weeds in the first place may not be applied in tank-mix with graminicides ("fops" and "dims"); otherwise, herbicide antagonism reducing grass weed control and soya bean injury may occur.

Avoid applying post-emergent herbicides under stressful conditions (at air temperatures below 15 °C or above 25 °C).

Recommendations for the chemical weed control measures in this publication are intended as a guidance and do not represent a complete list of herbicides, their potential combinations, nor any approval or support of any of these products. Danube Soya and the authors of this publication are not responsible for any possible mistakes in application of these plant protection products, which is not in accordance with label attached to every product.

3.6. Herbicide-resistant weeds and herbicide resistance management

Herbicide resistant weed populations are evolving very fast as a natural response to the selection pressure imposed by the repeated use of herbicides with the same mode of action. The development of weed populations resistant to the most frequently used herbicides is a real threat to current weed control strategies in soya beans. Careful management of herbicides, including integrated use of crop rotation, cultural practices and rotated use of herbicides with different modes of action are critical to minimise the development of herbicide resistance. Diversifying weed management practices and using multiple herbicide mode of action need to be more widely implemented.

When diagnosing herbicide-resistant weeds in field conditions, growers need to make sure that:

- *All other causes of herbicide failure have been eliminated? (Herbicide properly applied at the appropriate time and favourable weather during and following application, etc.)*
- *All other weed species on the herbicide label were controlled effectively?*
- *The field has history of continuous use of the same herbicide or herbicides with the same mode of action?*
- *The weed species that now demonstrates potential resistance was controlled effectively in the past by the herbicide?*

The previous table only contains the selective herbicides for use in soya beans. In the HRAC system, only one letter is used for herbicides or groups of herbicides that share the same mode of action. It is not necessary to know and understand every mode of action of herbicides, but you need to put into practice the labelling on the packaging and the instructions for use, however comprehensive they may be. Since the primary component of a resistance management strategy is to rotate herbicide modes of action or to use mixtures containing multiple modes of action the usage of classification codes is a valuable mean. If herbicides of group B are not efficient in controlling weeds (e.g. imidazolinone and sulfonylurea herbicides), they should be replaced or used in combination with efficient herbicides from other groups (e.g. C, see Table 3).

Herbicide resistance management programmes have to consider the use of all cultural, mechanical and chemical options available for effective weed control in each situation and utilise the following practices:

» *Practice crop rotations to keep any weed species from dominating. Rotations should include row crops, small grains and perennial forage crops.*
» *Where applicable, use tillage as a component of the weed management programme.*
» *Utilise cultural practices, reduce row spacing and maximise crop competitiveness.*
» *Scout fields and monitor for resistance and weed shifts.*
» *Keep accurate records.*
» *Use herbicide mixtures and rotate herbicides with different modes of action.*
» *Apply all herbicides at the right time and at the recommended rates.*

Soya beans infested by a biotype of Amaranthus retroflexus resistant to ALS inhibitors near Novi Sad, Serbia

Table 3: Herbicides classification according to the Herbicide Resistance Action Committee (HRAC)

HRAC group	Site of action	Chemical family	Herbicide
A	Inhibition of acetyl CoA carboxylase (ACCase)	Aryloxyphenoxy-propionates	Fluazifop-P-butyl, Fenoxaprop-P-ethyl, Haloxyfop-P-methyl, Propaquizafop, Quizalofop-p-ethyl, Quizalofop-p-tefuryl
		Cyclohexandiones	Clethodim, Cycloxydim, Tepraloxydim (not approved in EU)
B	Inhibition of acetolactate synthase (ALS)	Imidazolinones	Imazamox
		Sulfonylureas	Thifensulfuron-methyl, Oxasulfuron
C1	Inhibition of photosynthesis - photosystem II	Triazinones	Metribuzin
C2	Inhibition of photosynthesis - photosystem II	Ureas	Linuron (not approved in EU)
C3	Inhibition of photosynthesis - photosystem II	Benzothiadiazinone	Bentazon
E	Inhibition of protoporphyrinogen oxidase (PPO)	N-phenylphthalimides	Flumioxazin
F3	Bleaching - Inhibition of carotenoid biosynthesis	Isoxazolidinones	Clomazone
K1	Microtubule assembly inhibition	Dinitroanilines	Pendimethalin
K3	Inhibition of cell division (inhibition of synthesis of very long-chain fatty acids	Chloroacetamides	Dimethenamid-P, s-metolachlor, Pethoxamide
		Oxyacetamides	Flufenacet

Table 4: Herbicide injury symptoms on soya beans

Herbicides	Injury symptoms
Dinitroanilines (e.g. pendimethalin)	Injury symptoms include delayed emergence, swollen and cracked hypocotyls, stubby lateral roots and stunted plants. After pre-emergence treatment, under cool and wet conditions, callus tissue may appear at the soya bean stem from soil splash, followed by stem breakage and lodging.
Chloroacetamides (e.g. dimethenamid-P, s-metolachlor)	Injury symptoms primarily include inhibited plant growth and heart-shaped leaves due to a mid-vein growth inhibition in the leaflets. Symptoms tend to develop under cool and wet conditions, and when high rates are used.
Inhibitors of photosynthesis, photosystem II (e.g. metribuzin, linuron)	Injury symptoms include chlorosis and necrosis at the leaf margins and interveinal chlorosis on older leaves. Shallow planting and heavy rains can increase the potential for injury.
Plant growth regulators (e.g. dicamba, 2,4-D, clopyralid)	Injury is first noticed on newly developed tissue or leaves. Injury symptoms include stunting and inhibition of roots, improper root development, stunted and cupped leaves, strapping of veins, twisting of stems and petioles (epinasty). Injury may be caused by tank contamination and drift.
ALS inhibitors (imidazolinones and sulfonylureas – e.g. imazamox, thifensulfuron-methyl)	Injury symptoms include stunted plant growth, leaf yellowing or chlorosis of leaf margins, purple to dark red veins on the underside of the leaf. Slow development of symptoms following foliar applications. May be caused by carryover, misapplication, tank contamination and drift. Environmental stress can often increase the potential for injury caused by imazamox and thifensulfuron.
Pigment (e.g. clomazone, mesotrione, tembotrione)	Injury symptoms are bleaching and whitening of plants, which may lead to necrosis. Injury results from spray drift or carryover, symptoms occur in newly developed tissue.

3.7. Soya bean herbicide injury

Some herbicides may damage the crop when certain environmental conditions reduce the plant's ability to withstand injury. Always avoid herbicide application to a crop that is under stress or predisposed to injury. Apply all herbicides with a fully operational and properly calibrated sprayer at the recommended rates under the most favourable weather conditions and at the correct growth stages of the soya beans and weeds, and use a marking system to avoid overlaps in spraying. Herbicide injury in the field often display a pattern; it is often in stripes, occurs at field ends, or follows the movement of water and other soil-related conditions. Herbicides are sometimes blamed for soya bean injury caused by other factors which produce similar symptoms. The symptoms of injury may vary depending on the mode of exposure of the soya beans to a herbicide (soil or foliar application). In case of herbicide injury in soya beans, it is very important to pay attention to and document: the first date when phytotoxicity occurred, the plant parts injured and the severity of the injury, the speed and degree of plant recovery, herbicide drift across the field, overlapped application at the end of or across the field, the connection between the injury symptoms and the number of sprayer tanks emptied, injury in the form of uniform stripes caused by the sprayer, injury in different soil types, symptoms on weeds.


Injury symptoms caused by chloroacetamides (dimethenamid-P) after wet and cool weather conditions


Injury by pendimethalin applied pre-emergence following cool and wet conditions (left)and bleaching of leaves after drift of mesotrione (right)


Injury caused by pigment inhibitor (clomazone applied post-emergence; left) and Typical symptoms of injury caused by plant growth regulators (drift of 2,4-D; right)


Necrosis on old leaves caused by terbuthylazine (left) and Symptoms of necrosis caused by metribuzin on old soya bean leaves (right)

4. INTEGRATED DISEASE MANAGEMENT (IDM)

4.1. Introduction

Diseases can significantly affect soya bean yields and yield stability, and in times of epiphytotic outbreaks they can even question the profitability of soya bean growing. Over a hundred phytopathogenic microorganisms, i.e. causal agents of various pathological changes in soya beans, have been described worldwide. The most numerous and most damaging ones are pathogenic fungi, followed by bacteria and viruses.

Several soya bean diseases generally occur more intensively in certain agroecological regions, while others are either non-occurring or sporadic. In the Danube region, the most important foliar soya bean diseases are **downy mildew** (*Peronospora manshurica*) and **bacterial blight** (*Pseudomonas syringae* pv. *glycinea*), the main stem diseases are **white mould** (*Sclerotinia sclerotiorum*) and **stem canker** (*Diaporthe phaseolorum* var. *caulivora*), and the most common root disease is **charcoal rot** (*Macrophomina phaseolina*). Species of the genus *Diaporthe/ Phomopsis* are the most common and most damaging causal agents of **seed decay**. Additionally, there are several diseases that are potentially very destructive and have remained undetected so far on soya beans in this region, but should nonetheless be mentioned: **southern stem canker** (*Diaporthe phaseolorum* var. *meridionalis)*, **soya bean rust** (*Phakopsora pachyrhizi*) and **stem and root rot** (*Phytophthora sojae*).

This manual shows the distribution of the damages caused by the most economically important soya bean diseases in the Danube region. A separate section lists cultivation practices for efficient soya bean disease management.

4.2. Soya bean disease management and control

So far Soya bean diseases can still be managed and controlled by cultivation practices such as using resistant or less susceptible cultivars, crop rotation, healthy and quality seed. These practices reduces growing costs and are more environmentally-friendly. If this indirect measures are considered pesticides have not to be used to manage and control soya bean diseases, which reduces growing costs and is environmentally-friendly.

Developing and growing resistant or less susceptible cultivars is the most efficient and environmentally most acceptable disease management practice for all cultivated species, including soya beans. This practice completely controls some diseases, and partially controls others. The two most widespread foliar diseases can therefore be managed in these ways: Downy mildew can be completely controlled by growing more resistant cultivars and bacterial blight by growing late-maturing cultivars which are significantly less susceptible than early-maturing ones. White mould and stem canker are potentially the most damaging soya bean diseases, and all commercially available cultivars are more or less susceptible. It is well known that short-season genotypes most often avoid these infections and consequently should be grown in the most compromised areas.

Crop rotation is an important management practice because a multitude of causal agents of soya bean diseases survives in crop residues and the soil under unfavourable conditions. Planting soya beans on the same field is thus not recommended until the inoculum completely loses its vitality. Desirable preceding crops for soya beans are small grains, maize and sugar beet.

Most parasites are seed-borne, which is why healthy and high-quality seeds are considered one of the best disease management practices. In order to lower production costs, farmers use their own farm-saved, uncertified seed of unknown health status, which significantly increases infection incidence and severity. Soya bean seed crops are strictly monitored and checked for diseases during the growing season, and seeds are analysed in laboratories after harvest. The seed quality certification is issued for completely healthy seed only.

Disease intensity can be managed by applying other cultivation practices as well. The occurrence of white mould and stem canker can partially be avoided by early planting, but, on the other hand, early planting favours severe charcoal rot. Optimal planting dates are recommended for each growing region so as to promote fast and uniform emergence and avoid seed rot due to prolonged periods of seed dormancy. A dense plant stand causes the soya bean plants to become weak and prone to lodging, which favours infection outbreak and disease spreading. Early-maturing cultivars are less lush and tolerate a higher plant density, while late-maturing ones are more robust and require a reduced plant density. Irrigation causes most diseases to occur in a more severe form, especially white mould, which thrives in irrigated fields, thus cancelling out all advantages of this expensive cultural practice. Management of white mould includes the selection of cultivars resistant to lodging and the reduction of the plant stand in order to increase air circulation through the plant canopy, allowing the soil surface to dry faster. One of the rare soya bean diseases most effectively managed by irrigation is charcoal rot.

4.3. Downy mildew *(Peronospora manshurica)*

Symptoms of downy mildew: on the leaves (left); on the underside of the leaf (centre) and on the seed (right)

Downy mildew is the most widespread soya bean disease – it is regularly found in all soya bean growing regions in the world. It is particularly severe when the growing season starts off with rain followed by a prolonged dry spell. This fungus intensively spreads when the growing period sees frequent rainfalls, heavy morning dew, high relative humidity and moderate temperatures of 18–22 °C.

Downy mildew is most often observed on soya bean leaves and seeds, and can cause systemic plant infections when the plants grow from infected seed. The early symptoms are present in the stage of two to three true leaves, appearing as small pale yellow spots on the upper leaf surfaces. Under wet conditions, the spots enlarge and spread over larger leaf areas. Infected tissue becomes necrotic in time, turns darker and curled at the edges, wilts and falls off. The symptoms are also visible on the underside of the leaves, where the spots have a fuzzy crust. This coating is first light brown in appearance, and becomes purple in time, which is highly specific for downy mildew and diagnostic for this disease. The pods may also become infected, but the symptoms are only present in the interior of the pod and on the seed. The seed coat is partially or completely covered in fungal organs, most often around the hilum. Infected seed is usually smaller than healthy seed, with much lower vigour and viability.

Systemically infected plants completely lose yields, but their percentage is low, usually below 0.1%. Soya bean genotypes show a wide susceptibility range, from very susceptible to fully resistant. Good resistance sources provide the successful creation of resistant cultivars.

4.4. Bacterial blight *(Pseudomonas syringae* pv. *glycinea)*

Bacterial blight: early symptoms (left) and necrotic leaf spots (right)

Bacterial blight is the most widespread and most damaging bacterial disease of soya bean plants in the world. Infected seeds show significantly lower vigour and viability, and rot in the soil resulting in sparse crops. Matured plants infected with bacterial blight wilt and defoliate. Due to sparse crops and decreased assimilation area, yield losses can reach even 50%.

Symptoms of bacterial blight are found on the seed and all aerial plant surfaces (leaves, stem and pods) but are most common and most prominent on the leaves. Infected seedlings have stunted growth and die off when the symptoms reach the vegetative cone. In later developmental stages, the symptoms are visible on the lower and middle leaves, while under favourable conditions they may cover the whole leaf canopy. At first, the symptoms appear as small angular spots, yellow to light brown in colour. Later on, the spots enlarge considerably, often merging to form larger regular patches. The spot tissue dies off, breaks and drops out, leaving the leaf disfigured with holes and ragged at the edges.

Most commercial soya bean cultivars are highly susceptible to bacterial blight since the highly virulent race 4 is dominant in soya beans worldwide. Early-maturing soya bean genotypes are susceptible to this disease.

4.5. White mould *(Sclerotinia sclerotiorum)*

White mould: severe occurrence of white mould in the field (left) and symptoms on the stem (right)

White mould is potentially the most dangerous soya bean disease. It can cause plant wilting and rotting in the middle of the growing period. The damages are especially large when the plants are infected in the flowering and pod formation stages; in this case, the percentage yield decrease is almost identical to the percentage of diseased plants. The Danube region rarely witnesses severe occurrences of white mould, except for sporadic local outbreaks.

Initial symptoms of the disease are usually visible during flowering and pod formation, i.e. when the plant canopy closes. The top leaves first lose turgor, wilt and gradually wither. At first, they are grey to green in colour, later becoming darker brown. Wilted leaves remain attached and infected plants are thus easily identifiable. Due to intercepted water and nutrients supply from the root, the plants wither and rot completely. White fluffy cotton-like mycelium grows through the rotten plant parts. Symptoms on the pods and seeds differ depending on the developmental stage when the infection started. With early infections, the pods dry off completely before the grain filling phase and such plants have no yield whatsoever. If the grains were formed in the pods when disease struck, they remain small due to ceased grain filling. The pods may also be directly infected and become wet and soft with white mycelia growing out. Their seeds are flattened and with wrinkled seed coat. Sometimes they rot completely, and *sclerotia* form instead of seeds.

Moisture is very important for the onset and spreading of soya bean white mould. White mould occurs more severely in luscious, thick and lodged soya bean crop. There are no known resistant soya bean genotypes, and the situation is similar in other white mould plant hosts (over 400 plant species). However, there are variations regarding susceptibility levels. Late-maturing cultivars are more susceptible than early-maturing ones. Also, short-season cultivars are not physiologically resistant but avoid the pathogen attack.

4.6. Stem canker *(Diaporthe phaseolorum* var. *caulivora)*

Stem canker: symptoms on the stem (left) and prematurely wilted plants (right)

Soya bean stem canker is one of the diseases with the greatest economic effects. It causes plant withering and wilting as early as pod set; consequently seeds are either not formed or are small and shrivelled due to premature abruption of the filling period. If the infection starts early in the season, the symptoms will be severe and yield losses great. Later infection, naturally, shows milder symptoms and much lower yield losses.

Initial stem canker symptoms are visible after the soya bean reaches the reproductive growth stage. The most severe symptoms occur in pod set and grain filling. One or more nodes of the stem at the soil surface show slightly sunken lesions, elliptic or irregular in shape. In time, the lesions elongate and spread to adjacent internodes, reaching a length of up to 10 cm, and then take over the stem. The stem tissue becomes necrotic and girdled, so that water and nutrient supply from the root is cut and the diseased plant gradually wilts and dies. The top leaves of the infected plants show interveinal chlorosis followed by a gradual loss of turgor. The leaves then wither, wilt and die, but remain attached to the plant, making diseased plants easily identifiable in the field.

The soya bean is most susceptible from full flower to grain filling period. Therefore, if there is heavy rainfall in this period, severe occurrences of stem canker can be expected in soya bean crops.

There are no commercial soya bean cultivars fully resistant to stem canker, but there are vast differences regarding susceptibility levels. Late-maturing cultivars are highly susceptible because at the infection onset, they are in the early developmental stages. Early infection causes premature plant mortality and complete yield loss. Early-maturing cultivars avoid the pathogen attack and show much milder symptoms of the infection.

4.7. Charcoal rot *(Macrophomina phaseolina)*

Charcoal rot is a widely distributed soya bean disease that can occur in all growth stages and cause severe yield loss. During dry and hot summers, 40–50% crops may be infected, with 20–25% yield loss due to reduced pod and seed number on the diseased plants.

Charcoal rot usually infects the root and lower stem, but symptoms can appear on seedlings and young plants as well. When the weather is hot and dry, the seedlings dry off and die. If there is a wet and chilly period after the infection occurred, the seedlings will survive and continue to grow, but remain latently infected. Symptoms will be visible later on, when a prolonged dry period comes with high temperatures, showing first on the root as light brown spots that in time spread throughout the whole root system. Afterwards, they will show on the lower stem, lateral branches and, under favourable conditions, on the whole plant. On the infected stem parts, the epidermis breaks easily and vertical fissures appear, which is diagnostic for this disease.

High temperature is the main precondition for infections to occur and disease spreading. Soya bean plants are very susceptible to infection if previously stressed by drought or other stressors. Also, charcoal rot infection is most severe in early planting dates, and early-maturing soya bean cultivars are more susceptible than late-maturing ones.

Charcoal rot symptoms on the stem

4.8. Seed decay *(Diaporthe/Phomopsis* spp.*)*

The causal agents of seed decay are *Diaporthe/Phomopsis* spp. fungi. The disease usually occurs in regions with a hot and humid climate, when the soya bean crop matures. Infected seed has reduced seed quality parameters (vigour and viability), and sowing such seeds fails to produce optimal crop stand. Symptoms are characteristic and easily observable. Affected seeds are deformed, shrivelled or elongated. The seed coat is wrinkled and cracked, and is partially or completely covered with chalky white mould. Such seeds are slow to germinate and seedlings most often show signs of seedling blight.

The soya bean is most susceptible and the disease is most severe at the time of technological maturity. Wet and warm weather during crop maturation favours the development of this disease.

Seed decay (left)

5. INTEGRATED PEST MANAGEMENT (IPM)

5.1. Introduction

Approximately 180 animal species can damage soya beans, of which 150 belong to the class of insects and 30 to other classes. Only 25 of these species can be considered economically important for soya bean production. Furthermore, it has to be emphasised that the great majority of these pests are polyphagous and oligophagous, i. e. only a small number of them are associated with the soya bean only.

Although pests are not a limiting factor in soya bean production Integrated Pest Management (IPM) plays a significant role in plant protection. Good agrotechnical practice, especially crop rotation, sowing (time and quality), fertilisation, ploughing, inter-row cultivation, weed management, irrigation and harvest, are of special importance in IPM. With regard to a large number of plants per hectare, the soya bean is less jeopardised than row crops such as sugar beet, maize and sunflower. All measures that encourage the fast and healthy development of soya bean plants can be considered to be beneficial in decreasing the damage caused by pests.

In pest control, the following measures should be considered:

» *Fields should be scouted regularly and systematically for the presence of pests.*
» *Control measures should only be taken where a pest population approaches a profit-threatening "economic" threshold. The costs of applying a pesticide to a field with low yield potential may not be justified.*
» *When chemical control is needed, apply the lowest effective amount of the respective pesticide using equipment that is properly calibrated.*

5.2. Small mammals (rodents and hare)

5.2.1. European hamster *(Cricetus cricetus)*



European hamster (left), typical damages near a hamster nest (middle), poisonous baits left on the ground surface (right)

Description

The European hamster is polyphagous and can damage numerous plant species, including soya beans. It is mainly a nocturnal animal, but it can also be active at dusk and early in the morning. This pest lives in nests in the ground at depths between 0.5 and 1.2 m. Every nest consists of a few chambers some of which are used for living while others are used for food storage. In the chambers used for food storage, up to 50 kg of different seeds can be found.

Biology

European hamsters spend the winter months in their burrows in hibernation. Depending on the temperatures, hibernation can be stopped and feeding resumed with seeds collected during summer and autumn. In spring, activity is usually resumed in April when temperatures are higher than 10 °C on 6 successive days. European hamsters breed twice to 3 times a year. 2 to 3 weeks after copulation, 6 to 12 young are born. Hamster populations have declined steeply across Europe and even in Central and Eastern Europe, where higher numbers remain, some populations are on the verge of collapse.

Damage

The European hamster can damage soya beans during the whole vegetation period. Most damage is caused during emergence, when the young plants are easily damaged, and just before harvest when the hamster feeds on the seeds. Symptoms on the field are randomly distributed, usually appearing in circles around nests with damaged plants or even without plants. The size of a damaged area can be up to 70 m2. These pests can collect food more than 350 m away from their nests. Outbreaks are periodical, usually every 4 to 5 years, and last up to 2 or 3 years. Outbreaks are favoured by long and warm autumns, while long, cold winters with high humidity can be considered unfavourable.

Control measures

The European hamster is protected under the EU Habitats Directive 92/43/EEC, it is listed in Annex IV of the Directive. For this reason, EU Member States are obliged to take measures to ensure its protection and avoid deliberate killing or disturbance. Exceptions are only allowed in some special circumstances provided that no satisfactory alternatives exist and the derogation does not lead to a decline in populations.

5.2.2. Common vole *(Microtus arvalis)*

Description

The common vole is a small rodent with a size range from 9 to 11 cm. It lives in nests, up to half a metre in the ground, usually in couples.

Biology

The species is active all year round. Reproduction starts in March.

Signs for an activity of common vole

Damage

The common vole is a polyphagous pest which can damage soya beans during the whole vegetation period. In the vicinity of the nests, small winding trenches can be observed on the surface. The species can damage germinated seed in spring and, later in the vegetation season, young plants by eating leaves and stems, while prior to harvest, it can damage pods. It usually feeds on lateral branches, cutting them into smaller pieces and taking them to its nest. In the vicinity of the nest, soya bean plants are missing, and plants parts can be seen around and in the nest.

Control measures

It is advisable to take control measures against the common vole before outbreaks occur. Combining agrotechnical, mechanical and chemical measures is advisable. Earlier autumn ploughing can eliminate up to 90% of the individuals in a population. Another control tool are resting or landing posts for raptors which naturally hunt rodents like the common vole. Chemical control should be considered in case more than 200 active holes per hectare are found (Table 5; bolded levels are thresholds for chemical control). The holes which are used by voles are to be regarded as "active". In some fields, there are abandoned nests with a certain number of holes which are not in use. It is advisable to use spoon-shaped objects when placing baits. Direct contact with the baits should be avoided, and the use of proper gloves is mandatory. The baits should be laid directly into the holes and MUST NOT remain on the soil surface. After this, the holes should be covered with soil. Chemical control is usually done in late autumn and early spring. Trodden land, dirt roads and non-arable surfaces should also be included.

5.2.3. Field mice *(Apodemus spp.)*

Table 5: Rodent abundance categories and levels of damage

Category	Abundance description	Number of active holes per hectare		Damage
		Microtus arvalis	Apodemus spp.	
I	Very low	up to 10	up to 10	Up to 5% (low)
II	**Low**	**10–500**	**10–50**	**5–25% (noticeably)**
III	Medium	500–5000	50–500	20–50% (medium)
IV	High	5000–20000	500–2000	50–75% (high)
V	Very high	20000–50000	2000–10000	75–100% (very high)

Description

Field mice are small rodents up to 11 cm in length, similar to house mice.

Biology

This species also lives in underground nests. Field mice are active throughout the whole year. They have 5 to 6 matings per year and become sexually mature very early. For these reasons, there is great potential for outbreaks. Mild winters are favourable for the reproduction of field mice, unlike rainy springs and summers with less precipitation.

Damage

Damages are similar to the ones caused by common voles. Numerous ground holes and damaged plants around them can be seen in fields infested with field mice. In spring, field mice damage germinated seed and young plants; later in the vegetation season, they can damage plant parts and, prior to harvest, even pods. Sometimes, plant parts can be seen in the exit holes of the burrows.

Control measures

These are similar as for the common vole. Combining agrotechnical, mechanical and chemical measures gives excellent results. Autumn ploughing drastically reduces the number of mice. Some nests are buried by inter-row cultivation. Another control tool are resting or landing posts for raptors which naturally hunt rodents like field mice. A signal for chemical control is the presence of more than 50 active holes per hectare (Table 5). Baits based on zinc-phosphide can be used for chemical control. Chemical control is usually done in late autumn and early spring, and additionally if needed. Trodden land, dirt roads and non-arable surfaces should be included.

5.2.4. European hare *(Lepus europaeus)*

Damages on plants

Description

Adults can weigh up to 4 kg. A specific trait is the upper lip split up to the nostrils. The ears have black spots. All senses are well developed, especially the sense of smell.

Biology

The mating season is from January to August. Females breed 3 to 4 times a year, giving birth to 2 to 5 young per brood. After six months, hare become sexually mature. Populations of European hares have experienced a dramatic decline throughout Europe in recent decades.

Damage

The damage done by the European hare is specific as it cuts off the upper parts of the plant, usually just above the soil surface or a few centimetres higher. Plants are usually damaged in one row, following the movement of the hare. Parts of the field which are closer to groves and any other cover are more damaged. The soya bean is damaged over the whole season. Younger plants damaged by hare usually perish, while older ones can compensate a certain level of damage by lateral branching. During very dry years, hare can try to compensate the absence of water by cutting and feeding on soya bean plants.

Control measures

Hare populations should be controlled by hunting organisations. A better coordination between hunters and farmers is expected to give positive results. Where needed, repellents can be used. This kind of protection is not always reliable enough and it makes production more expensive. There are not many registered repellents for hare control. Potassium soap (conc. 1–2%), some organic fertilisers and mineral oils can be used. Aminosol (organic nitrogen fertiliser solution) has an unpleasant odour. It is used in the dose of 2 l/ha and prepared by mixing with 2 litres of water 3 days prior to application. Repellents should be handled with care and according to the instructions because some of them can be phytotoxic. If repellents are applied foliarly, it is enough to spray them on the field borders only. In case of rain, treatments should be repeated as long as the soya bean is susceptible to hare damage.

5.3. Insect pests at the beginning of the season

In early stages of growth, soya bean plants are very sensitive. That is why even smaller damages can cause considerable yield loss. In soya bean fields, the number of plants per hectare is greater than in fields with other row crops and therefore the impact of insects can be compensated more easily but still deserves consideration.

Insects can often be managed by agricultural practise, crop rotation, planting dates, tillage or weed management. Insecticides should only be used as the last measure. Before using an insecticide, producers should bear in mind that most insecticides reduce also beneficial insect populations and can cause secondary problems (e.g. spider mite outbreak in hot, dry conditions). The decision whether to use an insecticide depends on proper insect identification, understanding the pest's life cycle, the crop stage, pest abundance and various environmental conditions. Insecticide application that is not justified by an active pest population in the field is a waste of money. In order to get an accurate insight into pest abundance in the field, proper scouting is necessary.

Do not overestimate defoliation damage caused by insects. Soya bean plants have a high capacity to recover from insect damage, especially if the growing conditions are favourable. Some pests are aggregated near field edges (e.g. mites, some stink bugs). Partial treatments may be more effective if the damage is restricted to border rows.

In order to get an accurate insight into pest abundance in the field, proper scouting is necessary.

SCOUTING TIPS

- **Get an accurate picture of any problem that may need chemical treatment.**
- **Look for patterns and variations across the field. Don't pick out good spots or bad spots (many pest problems begin at field edges). Scan the field while walking from one site to the next**
- **Walk a random or diagonal course through the field and stop at a number of locations to look for damaged plants and collect insects.**
- **Many symptoms could be caused by several different conditions.**
- **Some pests are aggregated near field edges (e.g. mites, some stink bugs).**
- **Partial treatments may be more effective if the damage is restricted to border rows.**
- **If you find insects you do not recognise, consult the local extension service.**

5.3.1. Click beetles *(fam. Elateridae)*

Description

Adults are elongated and flattened, and usually dark-coloured (brown, dark brown, black, bronze). The head is wide and curved, and is not visible separated from the prothorax. Eggs are oval shaped, glossy, milky-white or yellowish in colour, and range in size from 0.4 to 0.8 mm. Eggs can hardly be seen because soil fragments stick to its surface.

Biology

The life cycle of click beetles lasts several years, usually 3 to 5. They overwinter as larvae of different stages and young adults. Eggs are laid on the fields under wheat, clover, alfalfa and some other crops with a high number of plants per hectare. That is why the highest number of wireworms in the soil can be observed after these crops. The cultivation of small grains, clover and alfalfa, monoculture or repeated sowing, less tillage or no tillage system as well as the presence of weeds are favourable to wireworm abundance. Soil humidity is very important because larvae develop when humidity is between 70 and 80% of full water capacity. In case the eggs have been laid in dry soil, larvae can easily dehydrate and die. After a few years of development, the larvae become pupae in the soil. In spring, the young adults become active and mate.

Damage

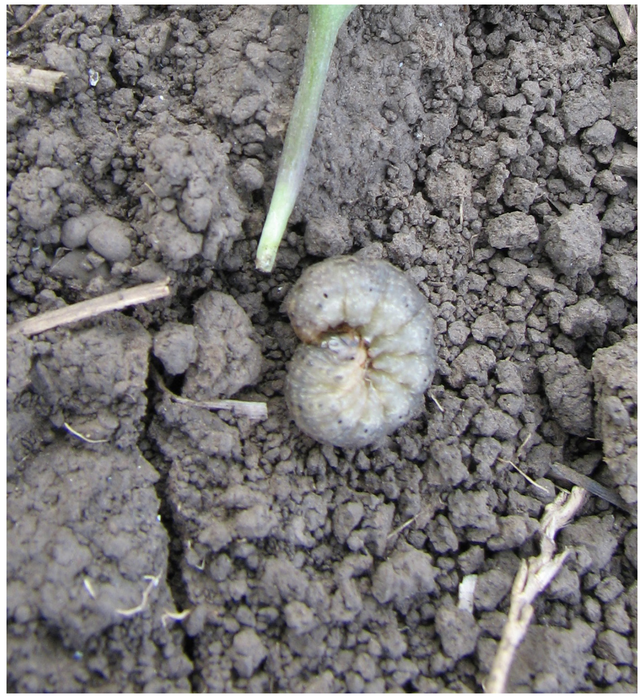
Wireworms usually feed on underground plant parts, stems or cotyledons. The biggest damage occurs in the period from germination until the 3- to 4-leaf stage. If the number of wireworms in the soil is considerable, even plants at the 6- to 7-leafe stage can die, especially in dry years. Typical symptoms are local circles with damaged or missing plants. Adults feed on vegetative and generative organs of different plants, but these damages are minor. The most frequent species are those of the genus *Agriotes*.

Control measures

Damage caused by wireworms can be controlled by IPM only, where agrotechnical, biological and chemical measures are important factors. Soya bean producers should know the approximate number of wireworms in the fields where they are planning to produce soya beans and act accordingly. Crop rotation and mechanical soil cultivation can reduce the number of wireworms. Ploughing can also be beneficial in wireworm control. Wireworm abundance, considering the long duration of larval development, can be forecasted, which is essential to reduce damage. Soil pest problems could be managed by insecticide seed treatment. However, due to the relatively small number of wireworms and the high number of plants per hectare, this method of control has not been widely adopted. No rescue treatment is possible!

Plant damaged by wireworms

5.3.2. Cutworms



Cutworm

There are three species of cutworms which are particularly dangerous for soya beans: turnip moth (also called common cutworm – *Agrotis* (*Scotia*) *segetum*), dark sword-grass (also called black cutworm – *Agrotis ipsilon*) and *Euxoa temera*. All three species belong to the family *Noctuidae*, the largest family in the order *Lepidoptera*.

Description

Moths are 2 cm long, with a wingspan of up to 5 cm. Forewings are darker, usually brown and grey, with a specific pattern for each species. Larvae (caterpillars) are greyish, usually up to 5 cm long, with 3 pairs of thoracic legs and 5 pairs of abdominal legs.

Biology

Cutworms produce two to three generations per year. After approximately one month, the adults emerge from the pupae, mate and lay eggs on the back side of the leaves of row crops with a lot of weeds. After hatching, the caterpillars begin to feed on soya bean leaves.

Euxoa temera has only one generation per year and overwinters as larvae. It damages soya bean plants earlier than the other two species, from the middle of April to the end of May.

Damage

Only the caterpillars are harmful. The damage caused by caterpillars of the first generation is greater than that by other broods. Caterpillars of the first, second and third instar only eat leaf parts between nerves. At later stages, they eat whole leaves or clip off young plants just above the soil and can reduce plant stand. This type of damage can be easily noticed in the field, where young plants are lodged on the ground, usually several in a row. The difference between cutworm and wireworm symptoms lies in the damaging spots on the plants, which are much bigger the case of cutworms. Sometimes, plants are literally cut off.

Control measures

Keeping the fields free of weeds is the most important control measure. Weeds should becontrolled throughout the whole vegetation period, especially in August, during the swarming of moths. Ploughing canreduce the number of cutworms. Autumn deep ploughing can reduce overwintering caterpillars buried deeper than 20 cm. Incase the economic threshold is reached (1 to 3 caterpillars/m2 in soil probes). Additional chemical measures are usually not needed. Only a few countries in the Danube region have approved insecticides for this pest.

5.3.3. Dipteran pests

Soya bean plants can be damaged by several species of the order *Diptera*. The most frequent one is the seedcorn maggot (*Delia platura*).

Description

Adults are greyish-black with stripes on the thorax, with an average size of around 6 mm, resembling a small housefly. The larvae or maggots are creamy-white, legless, and around 7 mm long. They are tapered at the head and blunt at the rear and have two dark spots near the end of the abdomen.

Biology

Dipteran pest species usually form two to three generations per year. Overwintering as a pupa in the soil. In spring, adults lay eggs at the soil surface. Larvae feed on all types of organic matter.

Damage

Only the larvae are harmful because they feed on germinating seeds and may damage the embryo, delaying development or killing the plant. Damage can be more severe during cold, wet springs.

Control measures

All measures that encourage faster germination and plant development can reduce damage. It is very important to use certified quality seed and sow the soya beans at the optimal time and depth. Sowing during cold weather and on fields with a higher amount of organic matter should be avoided. No rescue treatment is possible!

5.3.4. Maize leaf weevil *(Tanymecus dilaticollis)*

The maize leaf weevil is commonly found in areas with intensive maize cultivation. This is a polyphagous species which damages numerous crops.

Description

Adults are greyish and about 7 mm long. The species has an elongated rostrum, typical for weevils. Larvae are similar in size, white and legless.

Biology

The maize leaf weevil has one generation per year and overwinters as an adult on maize fields. It burrows underground, usually at a depth from 40 to 60 cm. Hibernated adults resume their activity in spring, when temperatures rise above 10 °C. The highest abundance is during April and May. After mating, the females lay eggs near plant species they feed on. Larvae spend their lives in the soil, feeding on roots, but do not cause economic damage.

Damage

Only the adults are harmful. The most sensitive period for soya bean plants is from germination until the 3-leaf stage (trifoliate leaf on the 3rd node unfolded = BBCH 13). Maize leaf weevils can damage the embryo, cotyledons and leaves during April and May. Adults produce a characteristic edge notching. After the plants have formed several leaves, the harmfulness of this species rapidly decreases. Dry and warm weather is favourable to this pest. Similar symptoms can be caused by the beet leaf weevil (*Tanymecus palliatus*), black sugar beet weevil

(*Psalidium* maxillosum) and alfalfa snout beetle (*Otiorhynchus ligustici*).

Control measures

Late sowing and sowing on fields after maize should be avoided. Good agrotechnical practice, crop rotation and all measures contributing to an optimal number of plants and fast growth can be considered to be beneficial in decreasing the damage caused by this weevil. In case there is an average of 3 to 6 individuals/m2 at the first stages of soya bean growth, chemical control is justified. For maize weevil control, insecticides registered for this purpose should be used.

Maize leaf weevil

5.4. Insects and mites – Pests of leaves and generative organs

5.4.1. Mites

Mites are economically the most important soya bean pests. Several species can damage soya bean plants but two are more harmful than others: the spider mite (*Tetranychus atlanticus*) and the red spider mite (two-spotted spider mite, *Tetranychus urticae*).

Field infested by mites

5.4.1.1. Spider mite *(Tetranychus atlanticus)*

Description

Mature females are 0.5 mm long and egg shaped. Summer generation females are yellow green, while winter generation females are more reddish. Males are smaller and yellowish, with a sharp-pointed abdomen. Eggs are oval and approximately 0.14 mm in diameter. Freshly laid eggs are glassy-white; later the eggs become more yellow. Larvae are around 0.5 mm long and yellowish, with three pairs of legs. Nymphs and adults have four pair of legs.

Biology

Mites have 10 to 14 generations per year. Overwintering females lay their eggs on weeds in spring. Weeds are intermediate hosts; after them, mites proceed to crops. Mites create colonies very fast. These are usually covered with a fine silky web which protects them from predators and adverse weather conditions. Colonies consist of individuals of all growing stages, which makes chemical control harder.

Damage

Population growth rapidly increases during June; in July and August, mites reach their highest abundance. Mites pierce leaves in order to suck sap, causing yellow dots which in time expand and merge. Infested leaves become yellow and may eventually fall off. Webbing may also be present under the leaves. Mites usually populate the upper, young leaves but in some cases of heavier infestation, whole plants can be covered with web. Damaged plants are smaller, with their transpiration being increased and photosynthesis being less effective. They also mature earlier, producing less pods and low yields. The first symptoms occur at field borders. Later, the whole field can be infested.

Control measures

Timely and adequate soil cultivation can reduce the number of mites especially if ploughing is done after harvest. Weed management is of great importance because weeds are hosts for several generations after which mites shift to arable crops.

Irrigation has beneficial effects on soya beans. It also negatively influences mite colonies, firstly by physically washing them off the leaves, and secondly by creating an unfavourable microclimate for their further development.
The economic threshold for chemical control is reached when 50% of plants with symptoms are observed on field borders or when there are, on average, more than 5 specimens on one leaf. Scouting should start at the end of June and continue during July and August. Early detection of infestation decreases damages and, in this case, chemical control of field borders will be sufficient. For chemical control, acaricides registered for this purpose in certain region can be used. In cases of severe attacks, spraying should be repeated after 7 to 10 days. For foliar application, it is suggested to use higher quantities of water and apply higher pressure because the colonies inhabit the back of the leaves. Treatments during the warmest hours have to be avoided.

5.4.1.2. Two-spotted spider mite *(Tetranychus urticae)*

This species is less frequent then the previous one. Adults are the size of salt grains and are greenish-yellow to brown, with two black spots. Morphological traits, biology, damage and control are similar to *Tetranychus atlanticus.*

5.4.2. Painted lady *(thistle caterpillar, Vanessa cardui)*

Painted lady butterfly

Painted lady caterpillar

Description

The painted lady butterfly has a wingspan of around 5.5 cm. Body length is 2 cm. Wings are very colourful, reddish with white and black spots. Light green, oval eggs are laid on leaves. Grown-up caterpillars are 4 cm long, hairy and dark brown in colour, with two yellow lines on the sides. The pupa is 2 cm long and silver brown in colour; it is attached upside down to soya bean leaves.

Biology

The painted lady is a migratory species originating from Africa and the Mediterranean. It has two to three generations a year. The first specimens can be seen in early spring. After mating, the females lay around 500 eggs on the leaves of various plants. The highest abundance occurs during June and July.

Damage

Only the caterpillars are harmful. When young, they eat leaf parts between nerves and later, in case of higher abundance, they may cause defoliation. Damaged leaves are tied together by web-forming larval nests. Caterpillars feed on weeds (creeping thistle, musk thistle, greater burdock, etc.) but also on soya beans. Damaged plants are typically grouped and localised.

Control measures

A very important measure is weed management. Chemical control should be used only when two or more caterpillars per plant are observed. When estimating the necessity for chemical control, apart from standard parameters, information about crop canopy conditions and larval instars should be included. Sometimes it is possible for chemical control to be managed locally in the field only. Not many insecticides are approved for this purpose. Only a few countries in the Danube region have approved insecticides for this pest.

5.4.3. Cotton bollworm *(Helicoverpa armigera)*

Pods damaged by cotton bollworms

Cotton bollworm caterpillar

The cotton bollworm is a polyphagous species which feeds on more than 250 plant species. It is a subtropical species which migrates from warmer climates such as the Mediterranean. This species is an economically very important pest of numerous crops.

Description

Caterpillars can be up to 4 cm long. They are very variable in colour, ranging from bright green to yellow to reddish-brown. Eggs are whitish and oval).

Biology

There are two to three generations per year. Overwintering as a pupa. The moths of the first generation migrate from mild climate areas and, after that, continue reproduction in continental areas. The development of one generation lasts between 25 and 40 days. Females lay around 500 eggs, mostly on generative organs. Caterpillars have 6 instars, followed by pupation. Adult moths fly from May to October, with a peak during July and August.

Damage

The highest intensity of damage is found on late-sown and post harvest crops. Caterpillars of the second and third generation are more harmful. Mild winters, hot and dry summers and temperatures higher than average are beneficial for the survival and reproduction of the cotton bollworm, and so are vast areas planted with potential hosts, irrigation, intensive nitrogen fertilisation, weedy fields, shallow and inadequate tillage, etc. The greatest damages occur during July and August, often accompanied by defoliation. Soya bean pods can also be damaged.

Control measures

Damage caused by the cotton bollworm can be controlled by IPM only, where agrotechnical, biological and chemical measures are key factors. Good agrotechnical practice implies sowing at the optimal time, a well-balanced fertilisation, weed management (for preventing additional pest nutrition) and early autumn ploughing (can destroy up to 90% of pupae in the soil). Chemical control should be used while the caterpillars are still in their early growth stages because as such, they are easier to control. Only very few insecticides (e.g.: chlorantraniliprole) are registered for control of Cotton bollworm. Good effects can be achieved using egg parasitoids of the genus *Trichogramma.*

5.4.4. Noctuid moths *(Mamestra* spp.*)*

Two species of the genus *Mamestra* are common pests in soya beans, the cabbage moth (cabbage armyworm, *Mamestra brassicae*) and the bright-line brown-eye moth (*M. oleracea*).

Description

Both species have a wingspan of 36–40 mm. The forewings are reddish-brown, with specific ornaments characteristic for each species. Hindwings are greyish, and the thorax and abdomen have the same colour. Caterpillars are green, ranging in size from 3 mm in the first instar to 40–45 mm during the last (sixth) instar.

Biology

They form two generations per year, overwintering as pupae. More precipitation, irrigation, high nitrogen fertilisation and the production of cabbage, peas and sugar beet are favourable for reproduction. Moths of the first generation fly during June, while specimens of the second generation can be found at the end of summer.

Damage

Caterpillars are polyphagous and can feed on more than 80 plant species. In cases of severe attacks, defoliation can occur. Damage caused by the second generation is far more important.

Control measures

Early autumn ploughing is of great importance. Chemical control is not commonly used.

5.4.5. Common Silver Y moth *(Autographa gamma)*

Description

Moths have a wingspan ranging from 40 to 45 mm. Forewings are brownish-yellow with a white spot in the centre, resembling the shape of the Greek letter gamma. The hindwings are light brown. Caterpillars are 40 mm long on average and light green with 6 longitudinal whitish lines. They move similarly to spanworms. Eggs are greyish white and flattened. They are deposited on the underside of leaves.

Biology

The common Silver Y moth is a migratory species. European populations are formed by specimens migrated from the Mediterranean. Moths are strong flyers and can travel great distances. This species has two to three generations per year.

Damage

The common Silver Y moth is a polyphagous species feeding on more than 100 plants. It is especially dangerous for clover, alfalfa, sugar beet, tobacco and soya beans. Outbreaks are rare. Caterpillars of the first generation are more dangerous and usually occur during June and July. They feed on stems and generative organs. In dry regions, irrigated fields are under more risk.

Control measures

These are similar as for the previous species.

5.4.6. Legume pod moth *(Etiella zinckenella)*

Legume pod moth

Description

Moths are grey, with an orange stripe on each forewing. The wingspan is 24 to 28 mm, and body length is around 18 mm. Caterpillars are up to 22 mm long and their colours vary from light green to grey and reddish. The pupa is brown and up to 12 mm long. It is enclosed in a silky cocoon with particles of soil attached to it.

Biology

The moth has two to three or more generations per year, depending on the weather conditions. It overwinters as a grown-up caterpillar. Flight begins in late May and is most intense during June, July and August. No clear distinctions can be made between the generations. Females lay up to 600 eggs on pods, separately or in groups. The eggs hatch after two weeks and the young caterpillars start to feed on the inside of the pods. Dry springs and summers are favourable for reproduction.

Damage

Caterpillars are polyphagous and can feed on more than 80 plant species. Females lay eggs on green pods. After hatching, caterpillars feed by drilling holes into the soya bean pods and later also into the seeds. Young caterpillars feed on the seed content, while older ones can destroy the whole seed. In one pod, there is usually one caterpillar which can destroy several seeds. Typical symptoms are partly or totally chewed seeds and damaged pods in which silky filaments can be seen. The second generation is more harmful.

Control measures

Biological methods imply the release of egg parasitoids of the genus *Trichogramma* during moth oviposition. Pheromones and light traps can be used for mass trapping. Chemical control is more appropriate for soya bean seed production because caterpillars damage the seed germ. The economic threshold is reached when more than 5% of plants with symptoms are observed in phenophases after flowering. Considering the possible overlapping of generations, two to three treatments may be needed. There are no registered insecticides for this purpose, but the control pattern is the same as for other lepidopteran pests.

5.4.7. Stink bugs

Not all stink bugs are harmful. Some are even considered beneficial. It is important to identify them at species level before any further step is taken.

5.4.7.1. Southern green stink bug *(Nezara viridula)*

Southern green stink bug adult and nymphs

Description

Adults are 12 to 15 mm long and 7 to 8 mm wide. The body resembles the form of a shield. There are three colour variants: One is light green and is named *smaragdula*; the other one has a brighter line on the head and pronotum and is named *torguata*; the third one is reddish-brown. All three variants have three distinct white dots and two smaller ones on the pronotum. All dots are in line with each other. The eyes are dark red or black. At first glance, this species can be easily confused with the green shield bug, *Palomena prasina*, which is also green. The green shield bug does not have white dots on the pronotum, and the larvae (nymphs) are not as lively coloured as the immature stages of *Nezara viridula*.

Biology

There are 4 to 5 generations per year. In late autumn, adults enter houses, buildings, barns, glass houses, etc. for overwintering. This is a Mediterranean species which expanded its habitat thanks to the mild winters of the last decades. After mating, the females lay up to 300 eggs in groups of 30 to 130 on the back of leaves. After hatching, the nymphs remain in groups until later instars.

Damage

The southern green stink bug feeds by piercing plant tissue with needle-like stylets. The feeding punctures are not immediately visible. Adults and nearly all nymphal stages (2nd to 5th nymphal stages) feed on a different plant tissues. Soft parts of the plant and the developing flowers or fruits are preferred. Feeding injury becomes visible sometime after feeding by turning dark. Even necrosis can occur. Feeding on flower buds results in premature abscission. The biggest threat for the seeds is damage in the early stages of formation. Feeding injury on pods results in seed damage and ultimately distorted development of the pods.

Stink bugs also have glands that emit a strong, characteristic odour. This species can be expected to become a more serious problem in soya bean production in the following years because of two major reasons: It is polyphagous and the acreage under soya bean cultivation is increasing.

Control measures

Insecticide applications are usually not required, but spraying may be needed if stink bug populations are high (the threshold is 8 to 10 specimens collected in 10 sweeps with a sweep net at the beginning of flowering). This pest can be chemically controlled using organophosphate compounds such as cypermethrin and others. Utilisation of trap crops (forage pea, bean, members of genus *Brassica*) should be analysed. The purpose of trap crops is to attract stink bugs to lay eggs on them, and subsequently do a chemical treatment before the bugs spread to adjacent soya bean plants.

5.4.7.2. Other soya bean bugs

There are more than 40 species of soya bean bugs. The majority of them are phytophagous, some are zoophagous and only a few are mixophagous. The most common species are the European tarnished plant bug (*Lygus rugulipennis*) and the alfalfa plant bug (*Adelphocoris lineolatus*). The damage caused by these species and their control are similar for all phytophagous bugs. The biggest damage occurs during seed formation.

5.4.7.3. European tarnished plant bug *(Lygus rugulipennis)*

Seeds of damaged and healthy plants

Description

Adults are 5 to 6 mm long and brown-green in colour, with dark spots. Larvae range from 1.2 to 4.4 mm, and have a green-yellow colouration. Wing formation occurs in the last instar.

Biology

It can be observed on soya bean plants in June, but the highest abundance occurs in July and August. This is a very mobile bug; adults can fly more than 2 km in search for food. In years with dry springs, adults shift from weeds to soya bean plants rather quickly because weeds become unsuitable for consumption. Dry and hot conditions are favourable, while cold weather and heavy precipitation have negative effects on this species.

Damage

Bugs can damage all soya bean plant parts above the ground. The feeding punctures bleach and burst, and soon necrosis appears; the flowers dry out and necrotic spots can be seen on the seeds. The biggest damage occurs during milky ripening. Seed production is more at risk because of decreased germination capabilities and the inhibited growth of damaged seeds. The presence of alfalfa in the vicinity of soya bean fields has a negative effect because the European tarnished plant bug develops and reproduces on it and then spreads to soya bean fields.

Control measures

Agrotechnical, biological and chemical methods can significantly reduce damage. Agrotechnical practice should be focused on ploughing, the use of certified quality seed, optimal plant stand, isolation, weed management, low mowing of alfalfa, etc. Damaged kernels in seed material should be removed. Sowing soya beans near alfalfa and on fields where soya beans were present in the previous year should be avoided. Insecticide treatments may be needed if plant bug populations are high. The threshold is 15 to 20 specimens collected in 10 sweeps with a sweep net at the beginning of flowering.

5.4.7.4. Alfalfa plant bug *(Adelphocoris lineolatus)*

Description

Adults are around 8 mm long, and greenish-grey in colour.

Biology

The bug has 2 to 4 generations per year. It overwinters as an egg. Nymphs hatch in spring and become adults in 20 to 30 days. High temperatures and low humidity are not favourable for their development.

Damage and control measures

These are are similar as for the European tarnished plant bug.

6. HARVESTING, DRYING AND STORAGE OF SOYA BEANS

6.1. Harvesting

Harvesting is still the greatest challenge in the process of soya bean production. Harvest losses can reach up to 30% of the biological yield due to inappropriate harvesting. Poorly adjusted harvesters and insufficiently trained operators are the main causes of high harvest losses. It might be said that actually the success of the harvest depends on proper control of harvest losses. Harvest losses are considered acceptable up to a level of 5% of the biological yield (e.g. 150 kg where the natural yield is 3 t). Three main factors should be taken into consideration when discussing on how to reduce harvest losses: **harvesting time, combine harvester** adjustment and the **harvesting method** itself.

Harvesting should start when seed moisture drops to 13–14%. It is also possible to start harvesting earlier, but then drying is required. If harvesting is late, losses will be increased and seed quality will be reduced. If the crop has developed in favourable conditions, the leaves will fall down and, within a few days, seed moisture will drop to the level optimal for harvesting. However, if the soya plants have been exposed to stressful conditions (drought, high temperature), the plants will go through their developmental stages faster and reach maturity earlier. Under such circumstances, the leaves mostly remain on the plants, while the pods and seeds are mature. This can deceive the farmers and disguise the right time for harvesting. Harvesting crops that are not mature is more difficult, while harvest losses in over-mature crops are high.

Commercial varieties usually possess satisfying pod shattering resistance, but what should not be ignored is that there is a biological limit to this resistance. If soya plants are mature and remain in the parcel for some time, exposed to rain and drying several times, favourable conditions for pod shattering are created.

A combine harvester that is well adjusted is essential for successful harvesting. Soya beans are most frequently harvested using a combine for wheat. Harvesting should be adjusted to parcel and crop conditions, which involves appropriate changes made to the harvester speed, airflow, drum revolution rate and sieves. Poorly adjusted combine harvesters increase harvest losses.

The harvester header should be in a horizontal position and combine speed should not exceed 5 km/h. Where weeds are present and in case of uneven maturity, the harvester should operate at a lower speed (3 km/h). The cutting height should be as low as possible (5–8 cm); this allows for harvesting the lowest pods as well. Now is the time when the importance of good seedbed preparation and the optimum plant population becomes evident. A floating flexible header with automatic cutting height control allows for the copying of the terrain and results in lower harvest losses. The header reel should be carefully aligned, and reel revolution should be synchronised with the harvester speed – it is usually 25% faster. The number of revolutions of the drum should be adjusted to 500–700 rotations per minute, depending on seed moisture. Seed moisture is also important for adjusting the drum clearance. In addition, the sieves are to be adjusted taking into account the seed size. Sometimes it is necessary to adjust the harvester twice a day because seed moisture may fluctuate depending on the time of the day. For instance, at the beginning and the end of the day, seed moisture may differ by up to 5% compared to seed moisture at noon.

PLEASE NOTE:

Desiccation (by glyphosate, diquat etc.) is a critical practice which is prohibited according to the Danube Soya Guidelines by harvest 2016.

6.2. Drying and storage

The optimum seed moisture for soya beans is 13–14%. However, if, for some reason (late planting, unfavourable weather conditions), it is vital to harvest when seed moisture is higher, drying will become necessary. Air temperatures in a dryer should be 55–60 °C and soya beans should not be dried longer than 30 minutes. They are of high value (human nutrition, seeds…) and should not be dried at temperatures higher than 40 °C. Low-temperature dryers should provide good air circulation around the grains. The soya bean has a quarter less resistance to air circulation than maize. It is necessary to monitor the air temperature and humidity during drying. Prolonged exposure to air with a humidity of less than 40% may cause grain cracks. Air that is too hot may cause over-drying of soya beans.

The temperature in the storage should be kept at 1–4 °C in the winter period and 4–15 °C during summer. These temperatures reduce mould and insect activity. It is recommended to check the moisture of the soya beans stored regularly.

THE GMO-FREE QUALITY SOYA OF THE DANUBE REGION

(Bosnia & Hercegovina and Serbia)

The project "GMO-free Quality Soya from the Danube Region" is commissioned by the German Federal Ministry for Economic Cooperation and Development (BMZ) and implemented in Serbia and Bosnia & Herzegovina by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. The project's aim is to use the participation of both these countries in the Danube Soya Initiative (DSI) and their commitment to the Danube soya quality programme as a lever to increase the competitiveness of their agricultural economies. GIZ and ADA are supporting the international Danube Soya Initiative (DSI) to develop GMO-free and sustainable quality soya under the Danube Soya brand. The cooperation stabilizes, upgrades and extends existing soya production, usage and processing in Serbia and Bosnia & Herzegovina. Jointly with the GIZ Project "GMO-free Quality Soya from the Danube Region" DSI establishes and starts operating the regional Danube Soya Competence Center in Novi Sad. The main activities of this center are to develop training curricula, to generate and disseminate best practices in farmer training and soya production and to establish a demonstration farm network. These efforts aim to set up sustainable value chains and inclusive buyer-seller relations certified under the Danube Soya quality guidelines. In addition, ADA is supporting DSI to establish an efficient quality management and monitoring system throughout the chain of custody of certified Danube Soya.

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(Page: 17, 46: ripe soya beans)

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