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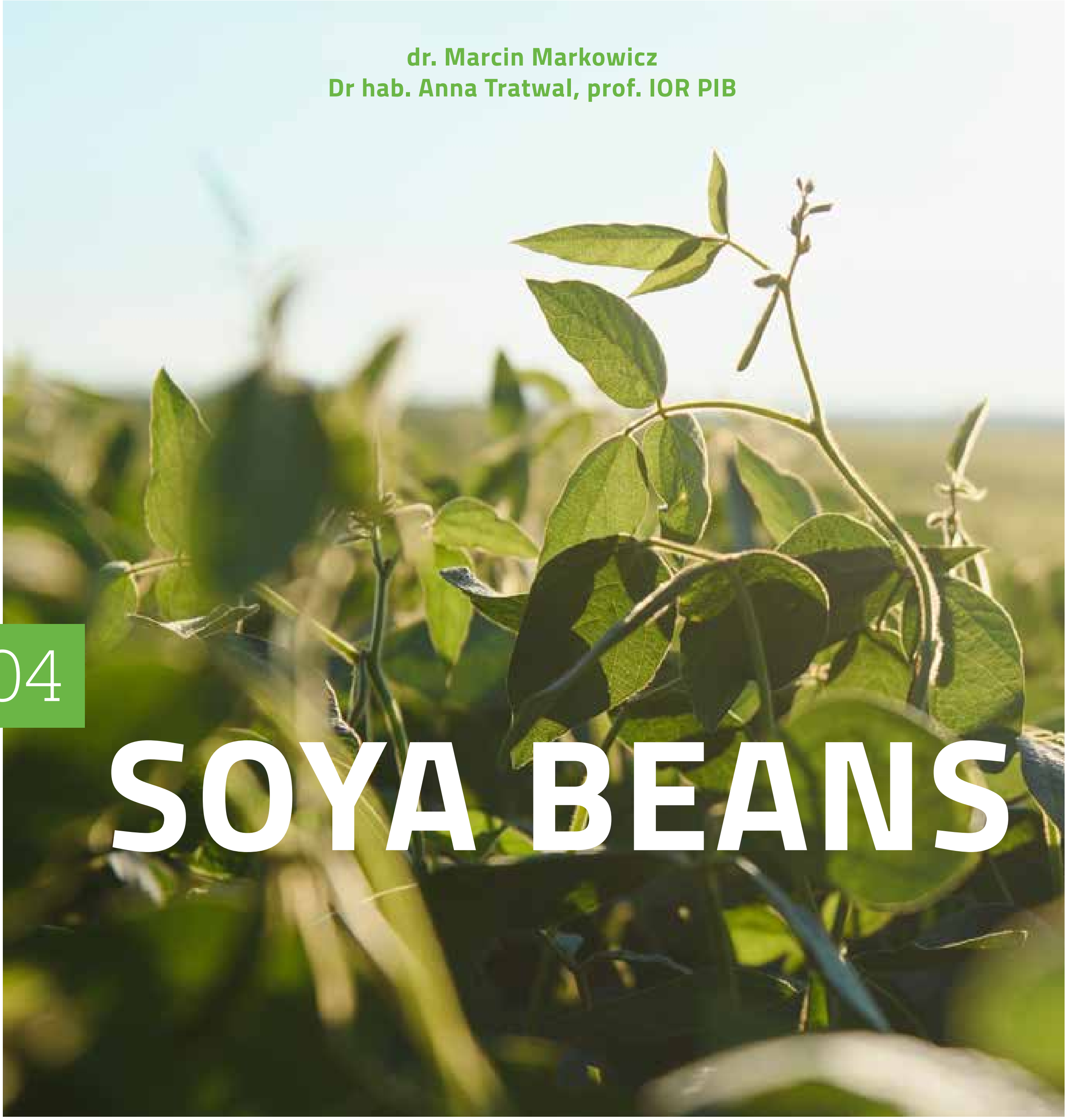

04

SOYA BEANS

CEE REGENERATIVE AGRICULTURE GUIDEBOOK

TERRA NOSTRA FUNDACJA
eit Food REGENERATIVE AGRICULTURE REVOLUTION
Co-funded by the European Union

CEE REGENERATIVE AGRICULTURE GUIDEBOOK SOYA BEANS

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Poznań 2023

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ECONOMIC IMPORTANCE AND BENEFITS OF SOYBEAN CULTIVATION

4.1

Soy is one of the most important crops in the world. In terms of acreage, soybean is the fourth crop in the world after wheat, corn and rice (FAO).

Its versatility is in the unique chemical composition of its seeds, with high protein and fat content and low fibre. The biological value of soy protein is very high, similar to beef (Kotecki et al. 2020).

In terms of its use, soybean is classified into oilseed plants, even though it belongs to the hard-seeded legume family, which has nearly 20,000 species, and their common feature is co-existence with nodule bacteria. Soybean cultivation is dominated by the US, Brazil and Argentina, which account for more than 70% of the world's cultivation area and more than 80% of the world's production (Kotecki et al. 2020).

According to American research, the success of soybean cultivation depends on the combination of weather conditions, soil type and genotype (Haegele, Below 2013). The cultivation of soybean, unlike cereals and rapeseed, is characterized by quick return on investment. The same machines are used for its cultivation and harvest as for the cultivation of cereals. Seeds after harvesting, in some particularly wet years, may require additional drying, but not to the same extent as corn. Soybean cultivation fits well into how agricultural farms are organised.

There are many benefits that a farmer can achieve by growing soybeans. Owing to the symbiosis of N2 with nodule bacteria, soybean plants have a reduced need for N-mineral fertilization. In addition, N2 bound by bacteria is not leached from the soil as quickly as N-mineral, which results in a more stable nitrogen pool in the soil. The reduction of mineral fertilisation with nitrogen allows a reduction in production costs and environmental pollution. In addition, soybean does not use up such quantities of water from the soil as corn, beetroot, rapeseed, which may be an important factor in years with scarce rainfall.

Soybean is a valuable forecrop crop owing to its beneficial effect on soil fertility and structure. A deep and strongly developed root system drains the soil well and absorbs leached potassium and nitrogen from deeper layers, as well as releases and absorbs phosphorus chemically bound to minerals, unavailable to other plants.

The cultivation of soybean brings many benefits in crop rotation, leaves very good conditions for the cultivation of cereals, rape or corn, reduces diseases and pests. In addition, it mobilises phosphorus from non-absorbable forms and results in increased mycorrhizal colonization of the subsequent crop, leading to increased phosphorus uptake (Kotecki et al. 2020).

SOIL REQUIREMENTS

4.2

Soybean requires medium-compact soils with good air-water ratios and structure. It does not tolerate waterlogged soils, heavy clays and deep sands (Herse and Szyrmer 1968, Peevy et al. 1972).

Fertile soil with high culture and good physical properties should be used for its cultivation. Soil for soybeans should be warm, airy and retain moisture well. Soils that are too compact are less useful for its cultivation, because in seed germination and plant emergence are hindered under those conditions. Soya does not tolerate acidic soils. Soils with pH of 6-7 are the most suitable, as the symbiosis between soybean and nodule bacteria proceeds properly with that value. If pH of the soil is acidic, the symbiosis is limited by the excessive concentration of aluminium and manganese ions, as well as the deficit of calcium, phosphorus and molybdenum ions. It is worth remembering that soybeans germinate epigeically - the cotyledons grow above the soil surface, which may be difficult in catchment area soils, if they become encrusted. Soya is not a good plant for soils that are too heavy, waterlogged and cold by nature.

The risk of erosion increases on compact soils and when the soil is not cultivated properly (lack of mulch).

BIOLOGICAL PROPERTIES

4.3

Soybean (Glycine) belongs to the bean (Phaseoleae) tribe. Among its many species, the most important is cultivated soybean - Glycine max (L.) Merrill. Soybean is an annual, spring, short-day plant (Kotecki et al. 2020).

The beans are smooth, yellow-cream in colour, oval or almost spherical in shape. The 1000 seeds weight of commonly cultivated varieties ranges from 150 to 250 g. Depending on the variety, the seeds contain on average 360-460 g·kg^{-1} of total protein and 210-230 g·kg^{-1} of crude fat in dry matter. Soybean germinates epigeically, which means that it emerges after a dozen or so days after sowing. It forms a well-developed root system, with a large number of lateral roots that can reach up to 150 cm in depth. About 95% of all roots are at a depth of 100-138 cm, but the main root structure is present in the tilled layer of soil, to a depth of 25 cm. The soybean stem is stiff, hairy, branching, and reaches from 50 to 120 cm in height, depending on the variety and growing conditions. The flowers form on the stem in the leaf axils, as clusters having from a few to a dozen or so flowers. Soybeans begin to bloom from the bottom up. The flowers are very small, self-pollinating, purple or white, depending on the variety. The leaves turn yellow as they mature and fall from the bottom part of the plant. In fields where soil variability is high, in valleys and other well-moistened fields, it matures a few days later. Its pods contain from 1 to 3 seeds, and even 4 seeds in the best locations with favourable rainfall distribution. The number of set pods and seeds in the pods is correlated with the amount of rainfall during flowering and seed setting. If there is drought, the number of pods and seeds in the pods decreases (Kotecki et al. 2020).

Specific structures known as nodules are formed on the roots of plants, where bacteria cells accumulate and multiply. In symbiosis with the plant, the bacteria bind atmospheric nitrogen (N2), which can then be used by the plant. The nitrogen fixated by bacteria is transported mainly in the form of ureides (allantoins and allantoic acid). In return, the host plant provides the bacteria with carbon and amino acids. This interaction is beneficial for the plants, as nitrogen tends to limit plant growth in terrestrial habitats (Kotecki et al. 2020).

Soybean forms a well-developed root system, with a large number of lateral roots that can reach up to 150 cm.

PLACE IN CROP ROTATION

4.4

Soybean is best grown after cereals, which leave the field free of weeds, and on soil that is moderately rich in nitrogen (too much nitrogen results in poor formation of nodule bacteria and may cause lodging).

In addition, like other legumes, it can be used to interrupt the succession of cereals, positively affecting their growth, development and yield. Its growing after the root crops has a negative effect on soybean, prolonging its vegetation. Corn can be used as a forecrop provided that the herbicides applied on it have already decomposed. Soybean is a very good forecrop for winter wheat, leaving the soil naturally drained and loosened, so contributing to value generation for the site, and the participation of legumes in crop rotation helps to reduce weed infestation of cereals and their infection by diseases caused by fungi.

Unfortunately, most farms are currently dominated by cereals, whose share in the sowing structure often exceeds 70-80%. In the coming years, a reduction in the acreage of potatoes and sugar beet can be expected, for which soybean may be an alternative, which, in addition to low farming cost, has a positive effect on soil fertility and capability.

Soybean is a very good forecrop for winter wheat, leaving the soil naturally drained and loosened.

BENEFITS OF SOYBEAN FARMING:

Enriching the crop rotation with legumes has a positive effect on the physical (soil structure), chemical (they leave significant amounts of nitrogen in crop residues or tilled biomass) and biological (they activate beneficial, structure-forming microorganisms) aspect.

More economical water management, because soybean consumes much less water from the soil than for example corn, beetroot or rapeseed. That is a clear advantage if the following years are dry.

Soybean coexists with nodule bacteria, specifically with the genus Bradyrhizobium japonicum - which fix free nitrogen from the air and provide soybeans with up to 150 kg N/ha.

A well-developed soybean root system reaches down to 150 cm, absorbs nutrients washed into the subsoil and transfers them to the tilled layer, and also perfectly loosens the soil.

So far, there is no threat from pests and diseases on soybean plants, and by including it in the crop rotation, it can reduce the pressure of pathogens on cereals and oilseed rape.

The same machines are used for soybean cultivation as for cereals or rapeseed, no additional farm investments are required.

As the condition of the agricultural environment deteriorates, and in the light of the requirements of the European Green Deal and the ever-decreasing quantities of plant protection products, soybean is becoming an ideal crop that prevents soil degradation and is a good fit for regenerative farming

Soybean in addition to low farming cost, has a positive effect on soil fertility and capability.

CULTIVATION – SITE PREPARATION FOR SOWING

4.5

To prepare a field for soybean sowing, we need to preserve the natural shape of the soil as much as possible and disturb its structure as little as possible.

After many years of using no-till systems, there is a significant improvement in the -physical properties of the soil due to the action of soil fauna.

The soil should be deeply loosened, but not inverted, which helps to cover the top layer with harvest or catch crop residues. This boosts humus formation in the soil.

Soybean cultivation in the regenerative system involves a complete departure from ploughing for soybean sowing in favour of simplified cultivation or direct sowing, and limits cultivation operations according to the principle „cultivate as little as possible and as much as necessary". No-till and direct sowing are defined as the abandonment of mechanical operations from harvest to sowing of the next crop. Ploughless tillage can cover the entire soil surface or only its strips (Jaskulski and Jaskulska 2016).

Ploughless tillage increases organic matter and make the soil more resistant to erosion compared to conventional tillage (Kladivko et al. 1986).

Plant residues and mulching left on the field surface are important in limiting erosion, which then reduces the risk of environmental pollution (Morris et al. 2010), and minimum soil disturbance combined with the constant supply of plant residues create favourable conditions for the development of soil and terrestrial organisms (Melero et al. 2011) and the protection of organic matter against rapid mineralization (Dzienia et al. 2001). Plant residues can also perform important functions by improving soil structure and stability and its organic carbon content, capable of modifying physical properties of the soil (Blecharczyk et al. 2007).

After many years of using no-till systems, there is a significant improvement in the -physical properties of the soil due to the action of soil fauna, which results in the formation of biogenic pores, mostly vertical (Anken et al. 2004). Under such conditions, despite the increase in the density of the surface layer, usually observed in uncultivated soil, the conditions for gas exchange and water permeability do not deteriorate. In addition, in ploughless systems, the plough pan is eliminated and the penetration resistance is levelled in the lower part of the soil profile. Plant residues remaining on the surface in no-till systems also improve soil carrying capacity and prevent crust formation, which in turn reduces surface runoff and increases water capacity of the soil. This is extremely important during rainless periods as the plants have a better water supply than in till systems (Morris et al. 2010).

Soil cultivation for soybean begins with forecrop harvesting. When the forecrop is cereals, it is crucial to spread the straw evenly over the field and mix it shallowly with the soil to increase the decomposition efficiency. Another cultivation procedure is to perform a 20-25 cm deep cultivation in late autumn. Soybeans, especially on medium and lighter sites, can be cultivated in the strip-till system. Here, the stubble is left untouched until sowing. If the forecrop left the field early enough, the sowing of catch crops, which protect the soil surface against erosion, also produces good results.

Plant residues left on the field surface are important in limiting erosion, which then reduces the risk of environmental pollution.

SOWING

4.6

Before sowing, check the temperature and moisture level of the soil.

Soybean does not tolerate sowing that is too deep, and the optimum depth is around 3-4 cm, depending on soil conditions.

According to Mota [1978], soybean sowing takes place in practice when the soil temperature is: in Serbia 8°C, in Bulgaria 12°C, in Japan, the United States, Colombia and Tanzania 13-29°C. In central and southern Poland soybean is sown at the turn of April and May. The temperature of the soil at a depth of 5 cm is then 12-14°C (Koźmiński 1981, Szyrmer and Szczepanska 1982). When the soil is cold, plant emergence is delayed and seeds are exposed to microorganisms. Frost additionally increases the loss of the plants. The phenological indicator of soybean sowing date is the flowering period of the Norway maple or the end of cherry blossom, usually from 20 April 20 to 5 May, depending on the region. An early date of sowing has a positive effect on the height of the lower pods. The highest seed yields are achieved with the seed density of 30-50 plants/m2. Soybean seeds often have a reduced germination capacity and a different 1000 seed weights.

The sowing rate per hectare should be calculated from the formula:

$$\frac{\text{seeding density per m2} \times \text{1000 seed weight}}{\text{germination capacity}} = \text{seed sown in kg/ha}$$

Soybean does not tolerate sowing that is too deep, and the optimum depth is around 3-4 cm, depending on soil conditions. It is best to sow seeds in rows of 15-25 cm in width, using a grain seeder. A precision seeder (e.g. for beets) can also be used at the spacing of 45 cm, provided that special sowing discs are installed. With the row width of 45 cm, greater competition from weeds should be taken into account because soybean plants form the canopy later.

SEED INOCULATION

4.7

Bradyrhizobium japonicum **soybean symbiotic bacteria do not occur freely, and the seeds must be inoculated before sowing in our soil.**

During treatment, soybean seeds should be handled gently, as they are very sensitive to any mechanical damage.

Proper inoculation ensures a large number of effective rhizobia in the rhizosphere, enabling rapid colonization and nodulation (the process of formation of root nodules). They are the main source of nitrogen supply for soybean, and thus determine the amount of seed yield. Papillary bacteria in the inoculation vaccines die even if transport and storage are incorrect. Freezing and high temperatures above 40°C are also deadly to those bacteria. The inoculants should be stored at 4-8°C and not exposed to direct sunlight or heat sources. It is also not recommended to use the inoculants together with fertilizers and plant protection products.

Inoculation should be performed in a cool, shaded room, depending on the type of the inoculant, immediately before sowing, of e.g. HiStick Soy, LiquiFix, Turbosoy or 120 days before HiCoat Soy, LiquiFix 120. Most of the available inoculants do not require dilution in water, but if the vaccine manufacturer recommends adding water, use water from a well or rainwater, and do not use chlorinated water.

During treatment, soybean seeds should be handled gently, as they are very sensitive to any mechanical damage, bruising, cracks, which reduce germination capacity. If we perform the inoculation on our own, we must remember that seeds may be destroyed if we do not do it properly or do it under poor conditions. Inoculation of small batches of seeds can be carried out in rooms with dimmed light, by gently mixing the seeds with the inoculum. In the case of a large number of seeds, this operation can be carried out using a conveyor belt, with the spraying of the seeds with the inoculant. If traditional seed treatment machines are used, the speed of the machine (screw conveyors) should be set as low as possible to prevent mechanical damage to the seeds.

The following may have an adverse effect on successful inoculation of the root system of soybean plants by *Bradyrhizobium japonicum* bacteria:

- ***sowing seeds on acidic and very acidic soils whose pH is below 5.0;***
- ***high sand content - over 80%;***
- ***sowing inoculated seeds into soil that is too dry or too moist, with a small amount of air;***
- ***stagnant water in the field;***
- ***inoculation using seeds previously treated with seed dressings that may reduce the number and size of bacterial colonies.***

Successful symbiosis also depends on soil contamination with heavy metals, as well as the presence of bacteriophages (viruses that attack bacteria) and some soil pests (e.g. weevils) that destroy root nodules.

Double vaccination of seeds produces very good results: the first by the producer of the seed material and the second on the day of sowing.

Inoculation can be carried out using a conveyor belt, with the spraying of the seeds with the inoculant.

FERTILIZATION REQUIREMENTS AND NEEDS

4.8

Soy is a legume, which means it needs plenty of available calcium, sulphur and some micronutrients such as boron, copper, manganese, molybdenum and zinc.

To produce 1 tonne of seeds, soybean absorbs about 75 kg of nitrogen, which means that, for a yield of 3 t/ha, it needs 225 kg/N/ha (of which 50-60% comes from the symbiosis with nodule bacteria). In most cases, the amount of nitrogen fixed symbiotically by soybean is not sufficient to obtain high seed yields, especially in the case of poor nodulation, extremely low soil nitrogen content at sowing, water stress, soil pH problems, low temperature or absence of Bradyrhizobium japonicum in the soil. Therefore, it is advisable in some cases to perform nitrogen fertilisation. Soybean is a biological crop, which means that high yields require biologically active soil. If the soil is in good condition, it is possible to achieve high yields without additional nitrogen fertilization

Soybean plants form a strong root system, which is characterized by its high capacity to absorb nutrients from the tilled layer and subsoil. The doses of potassium and phosphorus fertilizers are determined on the basis of the nutritional needs of soybean, soil fertility, forecasted seed yields. Maintaining adequate soil fertility in crop rotation should also be taken into account. On soils demonstrating medium to high abundance, it is recommended to spread in autumn about 40-50 kg P_2O_5 ha^{-1} and 60-80 kg K_2O ha^{-1}. For soil with lower abundance, the dose should be increased to 70 kg P_2O_5 ha^{-1} and 120 kg K_2O ha^{-1}. (Kotecki et al. 2020).

Soybean is a biological crop, which means that high yields require biologically active soil.

WEED, PEST AND DISEASE CONTROL

4.9

It is very important to control weeds on the plantation in the initial period of growth, i.e. from germination to the stage of 2-3 trifoliates.

To keep the soybean plantation clean, it is necessary to apply two herbicide treatments or use mechanical weed control. The first treatment should be carried out after sowing, before soybean emergence, using appropriate agents with primarily soil effect on well-moistened soil. The second spraying should be carried out as needed, after the emergence of plants when new weeds emerge. For monocotyledonous weeds, an extra dose of one of the graminicidal agents should be applied, in which case it is good to keep an interval of a few days between the different treatments. In the case of mechanical weed control, it is more advantageous to sow soybeans with a wider row spacing of 30-45 cm, which allows partial departure from chemical treatments and the use of weeders for mechanical elimination of weeds. An additional advantage of weeders is soil aeration, positively translating into plant growth if there is a heavy rainfall after sowing.

Many diseases caused by fungi are present on soybean, but as yet of minor economic importance. The same is true about soybean pests.

Many diseases caused by fungi are present on soybean, but as yet of minor economic importance. The same is true about soybean pests.

HARVEST

4.10

Soybean is ripe for harvest when the leaves fall. The pods are yellow-brown and the seeds turn yellow with a brown mark, harden and „ring" in the pods.

Varieties grown in Poland, depending on the region, are suitable for harvest in the third decade of September, or third decade of October at the latest. Harvesting is carried out at a grain moisture content of 13% by a combine harvester. The drying of the plants is longer and harvesting difficult if there is heavier rainfall and lower temperature..

Low cut matters - the disadvantage of most varieties is the low setting of the lower pods, which causes seed losses during harvesting. To prevent this, the cutting appliance should be set as low as possible to avoid cutting through the lower pods and leaving them in the field. Using a flex header for soybean harvesting is the best way to keep losses during harvesting to a minimum. The „flex" type header is characterized by a flexible cutting device and a different cutting angle, which allows the collection of all pods. Threshing should be done with the drum rotation reduced to about 500-600 rpm. The maximum water content in the stored seeds should be no more than 13% Soybean seeds are best stored at low temperature, from 5 to -5 ° C and relative air humidity of up to 70%. If seed material is produced, particular attention should be paid so that the seeds have as few bruises and cracks as possible, as this significantly reduces their germination. To prevent this, it is very important to properly „loose" the combine harvester already in the field and, if possible, to collect dry seeds to avoid their drying layer, because the seeds strongly knocked around heavily during their flow through the driers and hoppers.

The cutting appliance should be set as low as possible to avoid cutting through the lower pods and leaving them in the field.

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