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Good cropping practices and technologies to reduce the impact of natural hazards on maize production in Serbia

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This brochure has been developed as one of the outputs of the FAO project '*Enhancement of Disaster Risk Reduction and Management (DRRM) capacities and mainstreaming Climate Change Adaptation (CCA) practices into the Agricultural Sector in the Western Balkans'* (TCP/RER/3504).

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Contents

Rationale

Natural hazards, such as floods, droughts, storms, have steadily increased during the past few years. With climate change, it is expected that these hazards will increase in frequency and severity. According to the 2015 World Risk Index, the exposure of the population in the Western Balkan countries to such hazards is the highest within European region. Agriculture is one of the most climate sensitive sectors and thus highly vulnerable to climate variability and change. Given its importance to the Serbian economy, the people whose livelihoods depend on the sector and its activies may be significantly affected. These natural hazards may adversely impact crops, through leading to yield reductions as well as partial and total crop failure. The Serbian Ministry of Agriculture, Forestry and Water Management (MARW) is keen to increase maize producers capacities to reduce the adverse impacts of natural hazards on maize production. Therefore, MARW requested the Food and Agriculture Organization of United Nations (FAO) to facilitate the development of a brochure with good practices and technologies to reduce the impact of natural hazards. As part of the process, a Serbian panel of maize experts participated at the inception workshop held in Belgrade, Serbia on 26–27 September 2017 to discuss the current knowledge and practices in this area. This panel of experts included representatives of MARW, universities, research institutes, hydro-meteorological service, agricultural extention services, associations of farmers, maize producers, and private sector. The conclusions and recommendations from the workshop were summarized in a draft that was prepared by Milena Simić. At the validation workshop that was conducted on 16 November 2017, the manuscript was reviewed and supplemented with suggestions provided. This booklet lists all identified and validated good agricultural practices and innovative technologies that could help maize producers to reduce the impacts of natural hazards. The brochure has been developed as one of the outputs of the FAO project '*Enhancement of Disaster Risk Reduction and Management (DRRM) capacities and mainstreaming Climate Change Adaptation (CCA) practices into the Agricultural Sector in the Western Balkans' (TCP/RER/3504).*

The importance of maize

Maize originates from the middle part of America, from the present-day Mexico area. The name of maize in the language of the Mayan people means “the grain of life”, which indicates its significance for the survival of civilisations. For many nations, maize is a product, food, feed, commodity, fuel, building material, industrial raw material, medicinal and a decorative plant. Maize is one of the most important cultivated plant species. According to the sowing areas, maize ranks the third (after wheat and rice), while according to the amount of produced grain, it ranks second in the world. The areas cultivated with maize in relation to all other cereals in the Republic of Serbia are the largest amounting to over 50 percent, which present around 30 percent of totally used agricultural land. The Republic of Serbia is a significant producer of cereals within the European frames and the largest regional producer of maize with an average production of about 6 million tonnes.[1]

The classification of maize hybrids according to FAO maturity groups

Maize is a warm climate plant and for its growth and development requires relatively high temperatures and sufficient water supply during the entire growing season. All maize hybrids are classified into the international FAO maturity groups, depending on the length of the growing season. The FAO group 100 is the earliest and 700 the latest maturity group (Table 1).

[1]Source: *Statistical Office of the Republic of Serbia, http://webrzs.stat.gov.rs/WebSite/public/Report-View.aspx*

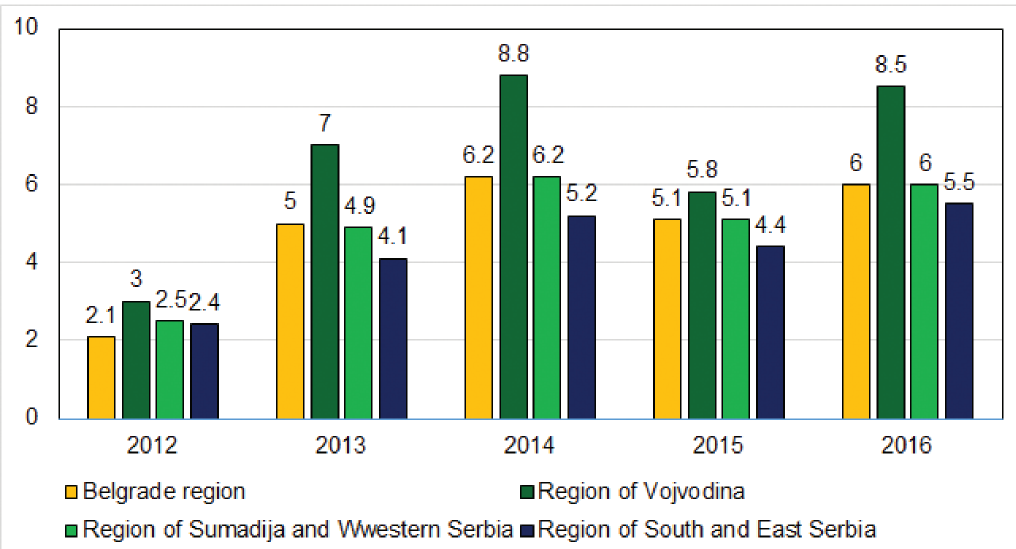

Figure 1: Average grain yield of maize (t ha-1) over regions in Serbia, 2012-2016,
Source: Statistical Office of the Republic of Serbia

Table 1: FAO maturity groups and the length of maize growing period

FAO maturity group	Length of the growing season (number of days)
FAO 100	105
FAO 200	110
FAO 300	115
FAO 400	120
FAO 500	125
FAO 600	130
FAO 700	135

Agroecological conditions for maize growth

In the course of their growth and development, maize plants undergo a series of developmental stages in which individual plant organs are formed - seed swelling, emergence, 3-leaf stage, tillering, stalk elongation, 7-, 9- and 11-leaf stage, tasseling, silking, blister, milk, dough, dent, full maturity. The yield of grain depends, to a significant extent, on how and under what conditions these stages occur. Maize plants sown in the optimal periods will have more favourable conditions (heat conditions, humidity conditions, etc.) for their development over certain stages than those that are sown outside the optimal deadline. The following sections describe the conditions necessary for the maize growth: soil, water, heat and light. In the years with unfavourable conditions and natural hazards (drought, heat waves, floods, frosts, hails, etc.), maize plants are subjected to stress, and the yield is threatened. Therefore, it is essential to adjust growing practises to reduce harmful impacts of natural hazards in order to obtain high yields of maize. The maize requirements regarding soil, water, heat and light are described below.

Soil – The highest yields of maize are recorded on loose and well-permeable soils with high water capacity. Soils containing great moisture reserves, eeasily available nutrients and at the same time well aerated, are favourable for maize cultivation. Such properties are characteristic for soils with a medium texture/mechanical composition

(medium and light clay) and soils rich in organic matter (chernozem and brown forest soil and similar). Heavy-textured, compact, saline, excessively wet soils, soils with a high ground water level and soils with increased acidity are less favourable for maize growing.

In Serbia, there are over 30 percent of soils with heavy mechanical composition (smonitza, pseudogley, brown forest soil, marshy black soil etc.). These soils, according to their properties, are potentially fertile, have good chemical, but unfavourable physico-mechanical properties. Only in years with the optimal precipitation amounts and their proper distribution, the fertility of these soils is evident. Such years are rare, and due to the high content of clay, soils of heavy mechanical composition are excessively dry or damp. The basic lack of compacted and heavy soils is that they are poorly supplied with air, which causes depression of the root system of maize, and reduces the number of useful soil micro-organisms. In such soils, the root system extends into the surface layer of the soil and when the dry conditions occur, the plant does not receive sufficient water supply, which affects the yield.

In order to obtain high yields of maize grain and silage on such soils, it is necessary to improve their quality. In the first place, their structure and capacity for water and air,should be improved, which could be achieved by incorporation of organic fertilisers, correct and timely tillage, application of crop rotation, introduction of lime to improve the soil reaction (pH), and other measures whose positive effects will be in particular manifested in the years with extreme conditions

Water – Maize has great demands for water, which is a decisive factor for its production in Serbia. Maize grown on well-permeable soils with good physical properties can utilise moisture from the depth of 1.5 to 2 or more meters. A necessary precipitation sum during the maize growing season amounts to approximately 570 litres/m^2. It is also important that maize plants are well supplied with moisture in the second part of their growing season (July and August) during the ear formation, flowering and until the end of grain filling. In the regions with insufficient precipitation sums and irregular distribution of precipitation, water should be provided by irrigation.

Heat – The temperature of the soil layer up to 10 cm necessary for maize seed emergence is approximately 10–12 °C, while the air temperature necessary for the intensive growth of maize should be over 13 °C. The temperature as a factor determines the rate of growth and the duration of the period from sowing to seedling emergence. Even after maize emergence, the impact of the temperature is great, as it affects the intensity of the plant growth in the early stages of development. If mean daily air temperatures are higher, the period from emergence to tasseling is shorter.

Light – Maize absorbs a great amount of light due to a large leaf area. It is considered that the optimum leaf area should be 40 000–50 000 m^2/ha. Such conditions provide the most favourable light regime and the highest plant productivity. With the further increase of the leaf area or the increase in the sowing density (these two factors are interrelated), the light regime, especially of the middle and lower leaves, significantly worsens, which reduces plants productivity. Maize does not tolerate shading, because shading effects significantly reduce the yield. The most favourable light regime can be provided by cropping practices, such as the crop density, nutrition level, soil moisture, variety selection, etc.

Natural hazards and stress in maize

Agricultural production significantly depends on meteorological conditions and due to it is susceptible to effects of natural hazards and climate changes. Maize hybrids have been developed to have maximum yields and yielding potential when appropriate growing practices are applied. However, natural hazards, such as, heavy rains, floods, storms, hails, droughts and frosts, as well as extremely low or high temperatures, can cause stress and may, to a significant degree, reduce or destroy the yield of maize. It is expected that with climate change, the number and severity of these adverse effects will increase. Effects of certain natural hazards on maize are described below.

Low temperatures – intensely slow down germination, root development and the growth of aboveground plant growth. Under prolonged periods (15 days) with low temperatures (up to 10 °C) maize seedling emerge late on the soil surface. Chlorosis (yellowing) is observed on seedlings, which is followed by wilting and dying of whole plants. If these plants survive, as a rule they are weakened, grow poorly, suffer more easily from fungal diseases, and sometimes they even die. The more humid the soil is, and the longer period of low temperatures it is, the injuries and damages on young plants are greater. Good nutrition and weed and disease control can help in the subsequent stages.

If maize seed germinates 2–3 days prior to the occurrence of low temperatures, and if the low-temperature period lasts a few days, almost all seedlings will be destroyed. If maize seed does not germinate prior to the occurrence of low temperatures (approximately 0°C), seed remains alive for a relatively long period.

As adverse effects of low temperatures increase with deep sowing into cold soil, it is necessary to establish carefully the sowing depth in accordance with the type of soil and expected temperature conditions. Furthermore, more resistant hybrids should be selected because they use reserve matters more quickly, which provides faster growth and development of plants.

Frosts – frequently occur in spring. Hard frosts (temperatures below –1 °C) completely destroy maize plants. At these temperatures, above-ground plant parts are mainly damaged or leaves are severely injured. Maize tolerates light frosts (–1–0 °C), and even damaged plants recover quickly if frosts are followed by warm and nice weather.

Plants shorter than 15 cm easily tolerate light frosts, but if their height is above 15 cm, they cannot tolerate light frosts. Autumn frosts are detrimental if they occur when maize plants are still green. They prevent grain maturation, due to which ears become soft and kernels lose germination.

Heavy rainfalls – have been increasingly occurring in spring. In the period between 2010 and 2017, four years were characterised with excess rains in spring. If water is retained on the soil surface, as it is almost a rule with clayey, poorly permeable soils and in micro-depressions (hallows), anaerobic airless conditions develop. Under such conditions there is no root respiration and plants cannot survive. Such soils should be drained (water should be drawn off) and soil mechanical and water-air properties should be improved.

Floods – If maize crop is flooded during the early stages of maize development (up to the 10-leaf stage) the damage is a complete. An insignificant number of plants survive, but their health is poor and the further production of such crop is senseless, i.e. no yield obtained would cover the costs of further production of such a maize crop. The best solution is to re-sow or sow new maize crop on the same surface if the agroecological and organisational conditions allows it. If the crop is flooded in the later developmental stages of maize, when the plants and ears have already been formed, the maize crop has a chance to recover if water quickly recedes. In that case, it is best to use maize for silage depending on the developmental stage of grain.

Stormy winds and hail – break and lodge the stalks, destroy the leaf areas of maize, often causing the complete loss of crops. Furthermore, the soil may be endangered due to wind erosion and

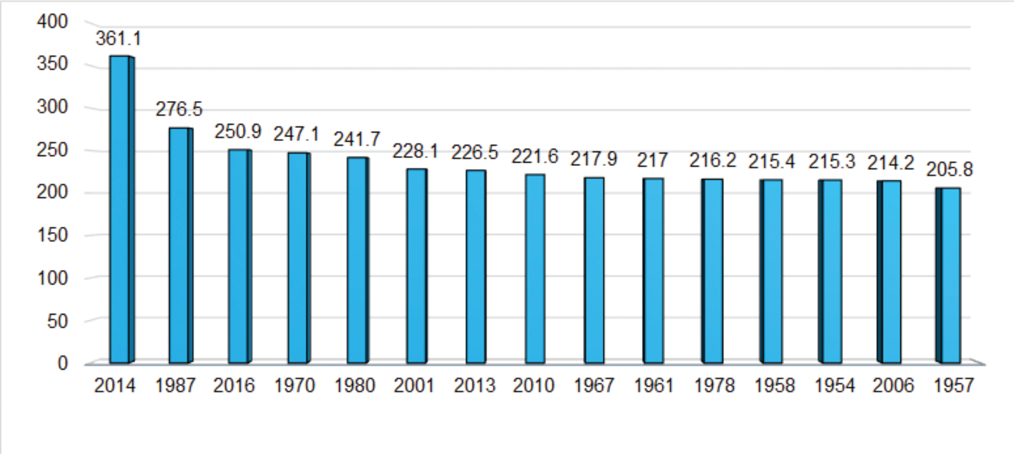

Figure 2: The years with the highest precipitation (mm) in the spring (Serbia, 1951-2016), Source: AgroLink, R&D Center, Serbia

dehydration. The instalment of windbreaks may help as they reduce wind erosion of the soil, increase the carbon fixation, biodiversity (biological diversity), etc. The instalment of windbreaks has to be planned, while planted trees have to be of high quality. Moreover, windbreaks may be agro-forestry systems (providing shelter from wind and protection from soil erosion), planted forests, planted covercrops for biomass, planted pasture plants for honey bees, etc. The selection of hybrids highly resistant to stalk breaking and lodging can partially contribute to the stability of maize production.

Soil erosion – Stormy winds, as well as heavy rainfalls, floods and hails may cause soil erosion, which degrades the soil, mostly by displacing its upper, fertile layers and diminishes its production capacity. Harmful effects of erosion, especially on sloping terrains, may be mitigated by actions that increase both, the content of organic matter in the soil and soil capacity to receive and retain water.

High temperatures and droughts – occur periodically but they are the most common problem for the global plant production. Due to climate changes, dry years have been more frequently occurring in Serbia. In addition to soil drought that occurs due to the lack of soil moisture, there is also dry air drought that occurs during summers due to the lack of air moisture. When there are no rainfalls and air temperatures are high, air loses moisture and becomes dry and warm. This leads to greater water loss from leaves, and water through the roots of maize is not able to compensate quickly for the loss. At that moment, air drought occurs and plants wilt. High temperatures and dry air may, to a significant extent, reduce the pollen function and pollination of maize, which leads to the reduction of yields. The greatest losses occur when the air and soil droughts occur simultaneously.

Although water demands by maize plants are great, maize is quite resistant to drought, particularly in the first part of the growing season (June and July). Due to well

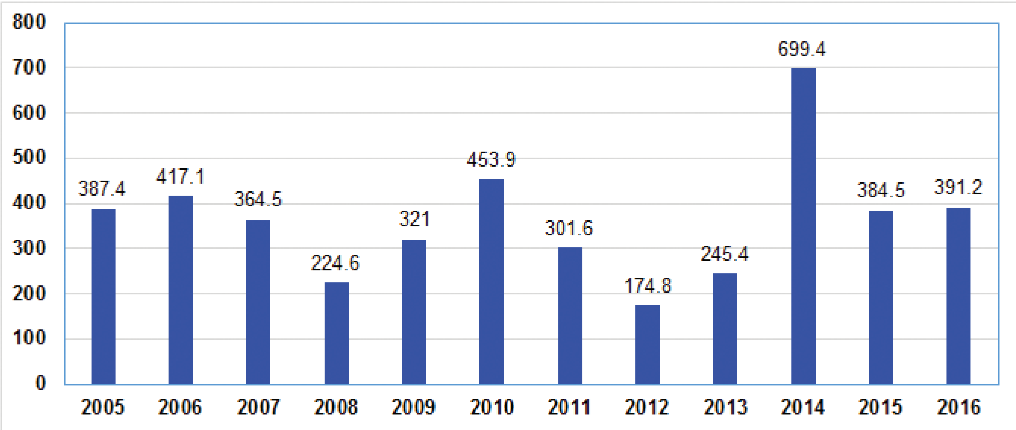

Figure 3: Precipitation (mm) of the vegetation period of maize, April-September, Zemun Polje (2005 - 2016)
Source: Maize Research Institute Zemun Polje, Belgrade

developed roots and leaves, maize plants use water economically and are well adapted to drought unlike many other crops. The maize root develops strong secondary roots that supply above-ground parts of the plant with water from deeper soil layers. The role of maize leaves in the survival of plants under arid conditions is important. Due to the fact that maize leaves are placed at a certain angle in relation to the stalk and due to their tube-like shape, plants can use even the smallest amount of precipitation, because water flows down the leaf towards the stalk and the root. In addition, during the dry periods, maize leaves roll in such a way and reduce the surface to prevent losing water.

In addition to the application of appropriate cropping practices, effects of drought may be mitigated by the selection of hybrids tolerant to drought.

Good agricultural practices and technologies to reduce the impact of natural hazards in maize production

Maize production consider appropriate growing practices and the most important are: crop rotation, soil tillage, subsoil tillage, mulching, fertilisation, sowing, choice of hybrids, weed and pest control, irrigation/ drainage and harvesting. The aim of this brochure was to contribute to the mitigation of effects of natural hazards in maize production through the recommendations of the appropriate cropping practices described below. The further sections describe maize growing practices within the cropping technology based on good agricultural practices (GAPs) that provide adequate growth and development of plants, i.e. enabling farmers to obtain high yielding maize under conditions of Serbia. Appropriately developed plants are healthy and vigorous, hence they better withstand fluctuations of environmental factors and are less susceptible to stress. In this regard, the application of the below stated GAPs is the base for the mitigation of effects of natural hazards in maize production. The omission of any of the stated GAPs or deviating from them is a neglect of plant needs during their growth and development, which causes plant stress and yield losses.

When referring to and describing GAPs, recommendations for their application are particularly emphasised when certain natural hazards are expected or it is known that they will occur. Recommended practices contribute to crop withstanding these hazards maintaining yield and grain quality as stable as possible with the least possible adverse consequences.

Crop rotation

Crop rotation reduces the negative influence of soil erosion, flooding, drought and pest and diseases.

Crop rotation means proper arrangement of crops in time and space in order to better use of soil potentials and climate. The proper application of this measure prevents the possible erosion and degradation of the soil, improves water management in the soil, reduces impacts of droughts and floods, and enables more efficient use of agricultural machinery, while reducing the costs. Crop rotation increases machinery efficiency use, together with expenses decreasing.

The advantages of cultivating maize in the crop rotation are numerous and they are reflected in the improvement of the chemical, physical and biological properties of the soil, more efficient and safe protection against weeds, diseases and pests. The most important advantage is the grain yield increase of maize grown in the rotation in comparison to maize continuous cropping.

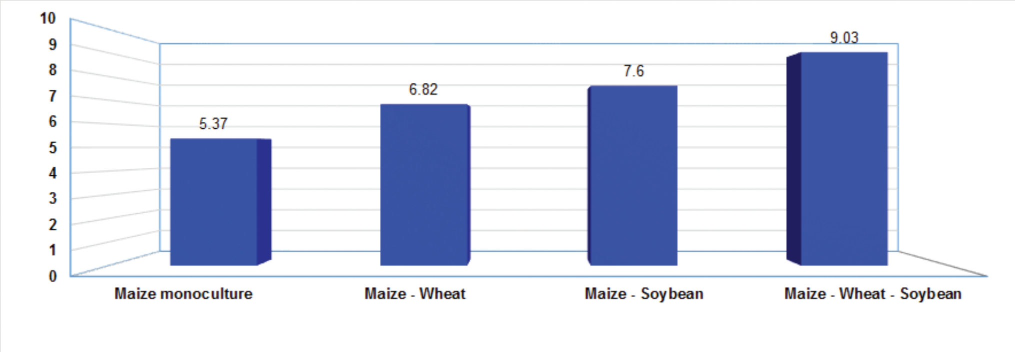

Figure 4: Maize yield (tonnes/ha) in different crops
Source: Maize Research Institute Zemun Polje, Belgrade

The efficient crop rotation is composed of crops with deep and shallow developed root systems, crops that uptake a big amount of nutrients and crops that enrich the soil, crops that consume big amount of water from soil vs. crops that accumulate and maintain the water in the soil. It is important to rotate different crops and their cropping practices in order to prevent spreading of weeds and diseases. Growing of crops in three- and four-crop rotations decreases the use of mineral fertilisers and herbicides. In years with unfavourable conditions for maize production, the effects of the crop rotation are even more pronounced.

Crop rotation is a fundamental measure applied to minimise weed infestation of maize, especially with troublesome perennial weeds such as Johnson grass, field bindweed, Canada thistle, Bermuda grass, etc., as well as to reduce weed seed bank richness in the soil as potential source of weed infestation in the succeeding crops.

Recommended practices and technologies:

1: when cultivating maize in the rotation, especially in years with unfavourable meteorological conditions and drought, care must be taken of the preceding crop. Maize should not be sown after sugar beet, sunflower, and other crops that dry out the soil.

2: continuous cropping should be avoided, i.e. cultivation of maize after maize because it reduces yields and aggravates pest control.

3: soybean (or other legume crop) should be included into the rotation because it is an excellent preceding crop to maize, leaves the soil with good physical properties and enriches it with nitrogen and contributes to higher yield achievement.

4: if a herbicide is applied, it should be checked whether there are any limits regarding a succeeding crop in the rotation.

Soil tillage

Soil tillage helps in flooding and drought influence reduction.

The proper soil cultivation contributes to the formation of a loose soil layer and the accumulation and moisture preservation, which leads to the improvement of the air-temperature regime of the soil, ensures the introduction of organic residues of the preceding crops and fertilisers, a better

distribution of soil herbicides and so on. Under irrigated conditions, soil tillage is of a great importance for maize yield increase, because it permits aeration of the top layer of soil and helps to integrate crop residues.

In order to protect the environment, in the last few decades, there has been a need to reduce a number of operations in soil tillage (reduced tillage) or sow directly into the soil with specially constructed drillings (direct sowing). Direct sowing also means saving energy, labour and machinery and helps prevent erosion and increases the efficiency of water and fertiliser utilisation.

In the majority production areas in Serbia, the different measures should be taken to collect and store moisture in the soil (proper tillage and fertilisation, autumn ploughing, summer ploughing, snow retention). These measures increase the soil water capacity and preservation, reduce erosion and water flow over the soil surface, waterlogging, as well as, flooding. Maize plants can use the stored water during periods of drought. It is well known that accumulated water increases maize yield.

Recommended practices and technologies:

Basic soil tillage

5: after harvest of small grains shallow ploughing should be conducted to the depth of 10–15 cm. At the same time, harvest residues and weeds will be incorporated in the soil, the organic matter decomposition will be accelerated and the soil will be enriched and its water and thermal regime will be improved.

6: conventional soil tillage should be conducted in autumn to the depth of 20–30 cm, depending on the soil type, the amount of harvest residues.

7: at the same time, organic and mineral fertilisers containing phosphorus (P) and potassium (K) should be incorporated. The soil over winter remains with open furrows to be exposed to the frosts, which contribute to a better soil structure and reduction in the number of pests.

Presowing tillage

8: in the early spring, pre-sowing cultivation should be done to the depth of 8–10 cm, in order to preserve winter moisture and prepare the soil for quality sowing. It is most often performed with combined machinery to reduce a number of passes. It is recommended to conduct pre-sowing cultivation in two steps: firstly, early in the spring (so called furrow closure) and the secondly, immediately prior to sowing.

Inter-row cultivation

9: inter-row cultivation of soil should be conducted before row closing of maize; in dry years it is recommended to apply two inter-row cultivations of maize if it is possible.

10: In case of two inter-row cultivation, conduct first cultivation in the 3–4-leaf stage of maize at the soil depth of 6–8 cm, while the second one is performed in the 6–8-leaf stage of maize at the lesser soil depth (4–6 cm) in order to prevent damage of lateral roots. Inter-row cultivation of soil helps in weed seedlings control, destroys soil crusts, provides soil aeration. In drought areas of Serbia, inter-row cultivation is more important than in the areas with sufficient precipitation sums. If the adequate amounts of fertilisers are applied and used herbicides are efficient, then inter-row cultivation is not necessary in maize cultivation.

Subsoiling

Subsoiling decreases a negative influence of heavy rainfall, floods and drought.

When cultivating the soil with a plough, the wheels of the tractor goes over a furrow and together with the plough, they compress the bottom of it creating the "plough pan"; soil compaction reduces its air and water capacity, which affects the biological properties of the soil, root system growth, reduces fertility and availability of nutrients to plants. Due to the existence of an impermeable layer, the root is poorly developed, remains very shallow

because it cannot penetrate into the deeper layers in the soil searching for water and nutrients, which also reduces the productivity of the plant. The formation of the impermeable soil layer prevents water movements. Water runoff into the deeper layers in the wet period is difficult, but also raising water from the lower into the upper layers during dry seasons is aggravated. Subsoil tillage helps in removing of surface water and water stored in the root zone and improves air capacity and structure of soil. Incorporation of organic matter into the soil by the application of manure and partial ploughing under the residues is one of the measures to improve the soil structure and to reduce consequences of treading.

Recommended practices and technologies:

11: in order to avoid the compaction of the soil below the ploughing layer and the formation of the so-called "plough pan", ploughing should be done every third to fifth year at a changed depth or reduced tillage should be applied.

12: if, however, a plough pan is formed, a subsoil plough should be used to break it, especially on heavier soils.

13: when deciding to the use of subsoil plough, it is necessary to take into account: the condition of soil moisture; the subsoiling depth; the amount and condition of the plant residues of the preceding crop; the available power of the tractor; etc.

Mulching

Mulching helps to reduce the impacts of soil erosion and droughts.

Malching is the covering of the soil surface with a protective material. Mulch is mainly of organic origin (straw and other harvest residues, hay, compost, dry leaves). It contributes especially to (1) the protection of soil from surface erosion caused by larger amounts of winter precipitation, especially on sloping terrains, (2) improvement of the physical properties of the land, (3) increased retention and efficiency of available soil moisture and nutrients for crop production, and (4) the control of weeds. The rule is that the land should be mulched when it is warming up at the end of the spring.

Recommended practices and technologies:

14: mulch can be applied if the maize is grown on smaller areas , but especially in the system of organic farming; soil protected by mulch requires less irrigation, weed control by hoeing and fertilization; it dries slowly, in the case of heavy rains it does not get stuck, it retains a loose, grain structure. Organic mulches eventually degrade and improve the quality of the soil and accelerate the growth of plants. Mulching reduces the need to use pesticides, and the cultivated crop has improved quality.

Cover crops

The use of cover crops helps mitigate the effects of excess precipitation, floods and erosion.

The cultivation of cover crops is a special way of overlaying/covering the soil. Cover crops reduce the runoff/leaching of nutrients from the soil and increase the content of organic matter and they should be cultivated in order to preserve the fertility of the soil.

Recommended practices and technologies:

15: on sloping terrains exposed to the effects of large amounts of winter precipitation, the cover crops protect the soil from surface erosion; the legumes - peas, soy and vetches, as well as cereals - rye, oats and others, should be used for this purpose, and especially mixtures of legumes and grain. Cover crops should be sown after harvest, in the late summer or early autumn, and left to grow during the winter. In the spring, cover crop should be destroyed, either by herbicides or rolling, ploughing in and crushing, at least two to three weeks before sowing of the maize; subsequently, sow maize into tight treated rows or directly with special seeders.

Choice of hybrid

Choosing hybrids that are more tolerant to natural disasters, can have a significant impact on ensuring yield stability, grain quality and cost-effectiveness of production. In order to reduce the harmful effects of natural disasters, it is necessary to cultivate hybrids that have stable yields and are adapted to cultivation in different agroecological conditions.

Hybrids are always tested according to the conditions of cultivation in certain regions (regionalisation) and the recommendations for their cultivation are given based on this. Instructions for selecting the most suitable maize hybrid for a particular region should be followed to increase productivity.

Recommended practices and technologies:

16: only certified seed of official producers of maize seed should be used.

17: in order to reduce the effects of summer drought, hybrids selected for yield stability and with wide adaptability to different agroecological conditions should be cultivated, as well as hybrids with shorter periods of vegetation (those which end the maturity stage before drought).

18: In regions with smaller amounts of precipitation in Serbia, such as Banat, Eastern Serbia and South Serbia, the hybrids of FAO group 300–400 or FAO 500 (115–125 days of vegetation period) should be used.

19: in areas where stormy winds and hails occur, the hybrids that are more resistant to lodging, i.e., with a lower stem, should be used.

20: the production of maize should be diversified through hybrids of different characteristics in order to achieve stable yields. In larger production areas, one and the same hybrids should not be cultivated, but several hybrids of different FAO maturity groups, in order to avoid the negative impact of meteorological conditions of the specific year, and at least some of the sown hybrids will produce good yields.

21: when choosing hybrids, the priority should be given to domestic hybrids that are selected in similar conditions of the climate in which the production of maize takes place.

22: follow the recommendations in choosing the most appropriate hybrid for each region to increase productivity.

Sowing

The proper time and sowing method, as well as the amount of seed, contribute to alleviating the harmful impact of almost all natural disasters.

The sowing ensures optimum conditions for normal germination and emergence of maize. Sowing should be harmonized with weather forecasts for a given year, with particular reference to the possible occurrence of drought, floods, etc. Sowing of high quality certified seeds, adapted to the hybrid in terms of density, should provide an optimal number of plants per hectare, with no empty spots. The sowing determines the size and shape of the vegetation space for each plant, in which it will have the necessary space for its development. The correct density of maize plants directly affects the yield.

The concept of maize sowing involves several operations (selection of hybrids, preparation of seed for sowing, sowing time, sowing depth, number of plants per ha, i.e. sowing density, and plant layout on the plot). The sowing time and density of maize are important because they affect crop biomass, lodging, efficiency of nutrient use, harvest time, etc. The optimum sowing time of the maize is not the same in the entire area of its

cultivation, but it is adjusted according to the agroecological and meteorological conditions of the region. Late sowing does not yield satisfactory results, especially in no-irrigation conditions, and in the case of FAO 600–700 hybrids. In such conditions, it often happens that later crops do not complete the vegetation.

Recommended practices and technologies:

23: the maize should be sown at optimum time, when the soil temperature is 10–12 °C; in Serbia this is most often in the second half of April; sowing of maize should be optimized and harmonized according to local conditions, in the same year there may be significant differences in micro location.

24: when low temperatures and frosts are expected, the sowing should not be performed before the recommended time; germination can be very slow, and the shoots can get damaged by frost.

25: the sowing density should be adjusted; large yields of today's maize hybrids can be obtained only if the required number of plants is planted on the unit of area/surface.

FAO maturity group	Optimal number of plants per hectare
300–400	70 000–80 000
500–600	60 000–70 000
700–800	60 000

26: maize seed should be sown at a depth of 6–8 cm in light soil, or 3–5 cm in heavy soil; sowing at the specified depths provides protection of seeds from low temperatures, allows the proper development of the root system and uniform emergence/sprouting; with favourable humidity and other conditions, the seed germinates in 10–15 days.

27: in case of drought - in early April, maize should be sown in a lower density, 50 000–10 000 seeds per hectare, than recommended for a particular hybrid (55 000–65 000 plants per hectare).

28: in case when spring floods destroy the crops, maize should be re-sown in the same field, using hybrids of earlier maturation groups and taking into account the restrictions regarding already applied herbicides.

29: the emergence/sprouting of maize can be slowed down or affected by many factors, mainly by the weather conditions and the incidence of pests such as click beetle, owlet moths, etc., so measures should be taken to protect the maize from insects (sow seeds treated with insecticide or introduce insecticide into the soil).

Inter-cropping

Inter-cropping helps to reduce the impact of natural hazards.

Inter-cropping enable greater stability and diversity of production better use of nutrients, light, heat, air, and vegetation space. Different crops usually have different root depths and plant heights and better tolerate unfavourable climatic conditions compared to pure crops (low and high air temperature, stronger winds, drought etc.). In a year with unfavourable climatic conditions, one crop can suffer more, while the other remains to compensate in some way.

Maize can successfully be intercropped with legumes (soybeans, beans and lupine). However, in addition to numerous advantages, this crop system encounters a number of limitations (e.g. mechanical sowing and harvesting, weed protection), which prevent its greater application in practice. Some of the disadvantages (presence of weeds, competition for light, nutrients, water, etc.) that accompany inter-cropping, are less affecting the second crop in the regular sowing, because crops live shortly together in the same area.

Recommended practices and technologies:

30: inter-cropping can be used for the production of fodder by combining maize and soybean which is compatible with maize from the standpoint of agro-technical practices but also from the aspect of nutrition.

31: inter-cropping is suitable for later sowing of maize and for conservation by ensiling; in this way, higher yields are obtained, as well as easier ensiling of maize and better quality of silage with more favourable protein to energy ratio. By combining maize and soybean crops, a more favourable relationship between protein and energy is achieved, which is significant for balancing rations for ruminants.

32: there are different models of intercropping, however, by sowing the maize and soybean in the same row it is possible to

mechanize all the operations from sowing to harvesting.

Fertilization and nutrition of plants

Proper fertilization helps alleviate the effects of drought. Application of optimum doses of fertilizers at the appropriate time reduces the runoff/leaching of nutrients during excessive precipitation.

Fertilization is a method of applying nutrients that help plant growth. The most important nutrients for the plants are nitrogen (N), phosphorus (P) and potassium (K). The fertilization provides the necessary elements for the growth and development of maize. Fertilization with manure improves soil properties, especially water - air capacity, which is especially evident when plants are exposed to stress in conditions of natural disasters. Under such conditions, good nutrient availability will help reduce the adverse impacts.

The application of mineral fertilizers to maize can be managed by time, place and amount of fertilization. Fertilization changes the relationship in the competition between crops and weeds, not only for nutrients, but also for other resources, so it is essential that the optimal quantity of fertilizers is provided to the plant at the right time and at the place from which it will best be used. Maize adopts substantial quantities of numerous macro- and micro-nutrients from the soil, and its requirement for elements of mineral nutrition is not uniform during the vegetation period. Nitrogen is absorbed very intensively at the beginning of vegetation, and the highest rate of absorption occurs in the period of flowering. After the start of the milk phase of maturity, the absorption of nitrogen slows down. Phosphorus is taken by plants in significantly smaller amounts than potassium and nitrogen, in the period of sprouting until the beginning of flowering. Potassium is most quickly absorbed from the soil in the process of seed germination and the formation of sprouts.

On heavy and substantially sandy soils, maize responds very well to manure fertilization.

Recommended practices and technologies:

33: before applying fertilizers, the soil should be analysed to determine the actual content of basic elements (nitrogen, phosphorus and potassium) as well as the soil reaction (acidity).

34: if the soil is highly acidic, it should be calcified (lime insertion and ploughing in) in order to repair it; the best soil reaction for cultivation of maize is pH between 6.5 and 7.2.

35: it is recommended that in the autumn the necessary quantities of phosphorus and potassium are applied into soil by ploughing in order to be translated into the forms in which the maize plant can absorb them, by spring.

36: the nitrogen fertilizer should be applied during the pre-sowing soil preparation, 10–15 days before sowing. In drought years, it is necessary to apply nitrogen fertilizer in early stages of maize growing or omit this procedure completely because this measure does not have a full effect during drought.

37: in order to protect agro ecosystems, it is possible to use foliar fertilizers in maize, mainly for the fertilization and especially if the fertilizer formulation allows for their joint application with plant protection products. Foliar fertilizers provide plants with microelements, as well as other physiologically active substances (amino acids, phytohormones, growth stimulators, etc.) necessary for easier overcoming of stress conditions and achieving higher yields.

38: for the repair and more efficient use of the soil, it is recommended to use green manure or sideration; it implies the cultivation of species, preferably leguminous, during winter or as a second crop, from July to October, and then plough them in the soil. As green manure different crops can be used such as winter peas, winter vetches, clover, etc.; legume plants fix nitrogen from the atmosphere and store it in their root nodules, thereby enriching the soil with nutrients and giving it a loose structure; soil that contains a large amount of organic matter has a greater ability to absorb and retain moisture.

Weeds and pests control

The suppression of weeds, pests and causative agents of maize disease is a particularly important measure because it contributes to a good crop condition, which then enables crops to better tolerate low temperatures, abundant precipitation and droughts.

Weed control helps to reduce the impact of drought on maize, because the weeds compete with maize for water, light, nutrients and vegetation; they help spread diseases and pests and reduce quality and yield. Usually

they consume large amounts of water, they obscure the surface layer and lower the temperature of the soil, utilize and remove a lot of nutrients from the soil and impede the implementation of agro-technical measures. Their detrimental effect has a decrease in yield as a lasting consequence, which is even more pronounced in conditions of natural disasters such as drought.

Maize diseases are most commonly manifested as disease of shoots, leaves, tassel, stalk and ear, as well as storage diseases. The most common are drying of shoots and root rot, less dense crops, crazy top (*Sclerophthora macrospora*), grey leaf spot, pink and blue-green and grey stalk rot, maize smut (*Ustiliago maydis*), red-yellow ear rot (*Fusarium* spp.), black-grey, yellow-green ear rot (*Penicillium* spp.), alternaria ear blight and septoria ear blight and others.

Pests in maize attack sprouts, young maize plants, leaf, root system, stalk and tassel, as well as ear, and they also occur in warehouses. The most common are click beetles, cockchafer, *Tanymecus dilaticollis (Coleoptera: Curculionidae),* owlet moths, flea beetles (*Phyllotreta* spp.) cereal leaf beetle (*Lema melanopus*), European corn borer (*Ostrinia nubilalis*), aphididae, Western corn root worm (*Diabrotica virgifera*), *Helicovepra armigera*, and others. Symptoms are uneven sprouting, eaten or drilled seeds cut off root neck or sprout. On the maize leaf, damages occur in the form of spots, holes and burns. Lodging of plants can also occur, broken and dropped tassels, silk damage, eaten grains, crushing and drying of plants may also occur, and ears that have fallen off.

Recommended practices and technologies:

39: for planned and long-term reduction of weed infestation combine preventive measures (crop rotation, cleaning machinery of weed seeds, cutting along roads, railways, and canals, etc.), and direct measures (cropping and biological measures, hoeing and chemical measures). For the successful implementation of such a system of measures, a good knowledge of the field and its history is needed, first of all in terms of the application of herbicides; it is therefore necessary to keep a field book.

40: good cropping measures that should be applied for successful weed control in maize are crop rotation, soil cultivation, crop density, more competitive hybrids, cover and inter-crops, etc.

41: apply inter-row cultivation of soil; cultivation between rows is a very effective traditional measure that reduces the weed infestation, breaks up the superficial soil layer and keeps moisture in the soil; maize responds well to inter-row cultivation; if it is possible, two inter-row cultivations should be applied.

42: if the soil has sufficient moisture after sowing, the herbicides should be applied before the emergence of the maize (pre-emergence) and immediately at the beginning of vegetation the weeds should be suppressed.

43: in drought years, the efficiency of soil herbicides is usually low, so herbicides should be applied during the maize vegetation (post-emergence).

44: a new approach to weed control in areas where perennial grass weeds are common, such as bermuda grass (*Cynodon dactylon*) and quackgrass (*Elymus repens*), is the sowing of hybrids tolerant to the active substance cycloxydim. In combination with crop rotation and proper soil treatment, this measure addresses the problem of presence of these problematic species in maize crop.

Irrigation of maize with typhoon

45: for the control of most maize diseases, develop the system based on combined application of measures. In addition to chemical measures, it is important to select hybrids with increased tolerance to disease causers, to use quality seeds treated with fungicides, also timely sowing, optimal plant density, weed control and pests, keep soil with favourable air/water regime and good balance of nutrients, timely harvesting, take care of harvest residues, etc.

46: for the successful control of pests in maize, a system should be developed which combines mechanical, agro-technical (crop rotation, crop density), biological and chemical measures; chemical measures involve the use of insecticides by treating seeds, foliar or using air treatment when attacks occur on larger surfaces.

47: birds also can cause damage to maize by consuming seeds and emerging sprouts, which is particularly pronounced in dry years because the sprouts and young maize plants are the source of water for birds. If there are permitted repellents, they should be applied to seeds before sowing; another way of protecting maize from birds is the installation of various mechanical devices (artificial birds, electronic repellents, etc.) in the field.

Irrigation

Irrigation helps to reduce the impact of drought on maize.

Irrigation is the application of water in controlled quantities and certain intervals to the soil or plants in order to support the optimal growth and development of crops. Irrigation activates microorganisms and reserves of nutrients and contributes to better utilization of applied fertilizers. Since maximum yields can only be expected under conditions of good soil supplied with water, irrigation is the only effective way to overcome the problem of water shortage in maize production.

When applied together with fertilization, in years with average agroecological conditions, it can contribute to increase in maize yield by 15–30 percent, and in very dry years, the yield may be higher several times.

Recommended practices and technologies:

48: apply irrigation if it is possible because it is an effective way to overcome the problem of drought in the production of maize. Maize plants should be supplied by water especially during the critical period, which in maize crops starts 15–20 days before silking stage and lasts until the beginning of milk maturity.

49: the difference between the quantities indicated (450 to 600 mm of water during the growing period) and the amount of rainfall should be compensated by irrigation. Approximately, monthly requirements are shown in the table below.

50: the norms of irrigation should be adapted to climate conditions, soil type, hybrid requirements, etc.

Month	Irrigation norm (mm)
April	35
May	90
June	95
July	120
August	75
September	40

51: on irrigated areas, stable yields are achieved, and there are conditions for growing maize as second crop; growing maize as a second crop can produce grain, but yields are smaller. In stubble crop sowing, significant quantities of row biomass can be produced which can be conserved by ensiling. For stubble crop production, use hybrids of shorter vegetation (FAO 100 to FAO 400). Sowing should be done at the latest in the first week of July.

Drainage

Drainage primarily contributes to the mitigation of the effects of excess precipitation and floods.

Drainage is a measure of removing excess water from the soil surface and from the root zone of the plants, which provides better aerial quality and soil structure.

Recommended practices and technologies:

52: regularly maintain drainage canals and clean them from weeds and waste, in order to allow seamless flow of surface waters and prevent flooding.

53: apply vertical soil treatment using sub-soilers before ploughing on hard soil where water is remains on the surface in the spring to make it more permeable. Sub-soil treatment corrects the physical properties of compacted soil (compactness) and allows the accumulation of water in deeper layers, that is, reduces the risk of rapid soil drainage during summer.

Ensiling

Ensiling of maize provides a higher amount of nutrients units per hectare, especially when yields are lower due to natural disasters.

Flooded soil in spring

Water retention on the surface of the soil

Maize biomass belongs to a group of biomasses that always ferment well with the proper silage technique and provide good, stable silage. Maize used in the form of silage has a higher nutritional value and provides greater production of milk and meat compared to utilization of maize in form of grain. The relative utilization of maize biomass through silage is higher in the case of lesser forage yields that can occur in drought years.

Recommended practices and technologies:

54: in drought conditions, when low maize grain yield is expected, use a maize for a silage; maize is grown in Serbia for silage, by sowing hybrids especially created for silage.

55: for silage, use maize hybrids with a longer vegetation period (FAO 600–800); these hybrids develop a lot of green matter and have a well-balanced relationship between green mass and ear, they are well compressed and stored.

56: use for silage a “stay green” hybrids which allow the leaves to remain green even in stressful conditions with the sudden appearance of high temperatures and drought periods.

Harvesting

Timely harvesting helps alleviate the effects of excess precipitation and low temperatures.

Harvesting is one of the most important processes in maize production and should be done properly in terms of weather, mechanization and condition of crops. A good selection of hybrids is of great importance, especially at slightly higher altitudes and in subsequent sowing times. Inappropriate harvesting time or improperly adjusted mechanization can reduce the already achieved maize yield by up to 20 percent. In drought years, maize harvest must be done earlier in accordance with the FAO group of hybrids, while in wet years plant maturation can be shifted for several weeks.

Recommended practices and technologies:

57: timely harvesting of maize; harvesting should be done when the grain is in full maturity, stems are dry, and moisture in the grain is low; harvest that is done on time

Maize harvest

leaves enough time for the fall ploughing to be completed in the most optimal time.

58: maize should be harvested when the grain contains less than 20 percent moisture to avoid the harmful effect of early autumn frosts.

59: the machinery should be set up for harvesting according to the environmental conditions and conditions of the crop.

60: maize grain is stored with 14 percent moisture, and if the moisture is higher, the grain should be dried before storing it.

Summary

Maize (*Zea mays* L.) is the number one crop in terms of area and production in Serbia. Maize plants go through several stages during their growth and development. The length of individual phases is different and depends on the type of soil conditions, the hybrids, applied measures of cultivation and others. All hybrids of the sorted numbers are the labels in the FAO group, depending on the length of the vegetation period. Maize is a plant that thrives in warm climates as it requires high temperatures and sufficient amounts of precipitation during the whole growing period. Maize gives high yields on loose and porous soil with good capacity for water and which contain easily accessible nutrients for plants. It is very important that the plant is well supplied with moisture during the second part of the growing season (July and August), during the formation of the cob, until the end of flowering and grain filling. Maize accumulates a large amount of light due to its large leaf surface. Natural hazards, such as frosts, heavy rains in spring, floods, storms, hail, droughts, cause stress and to a significant degree reduce or destroy the maize yield and can lead to substantial crop losses.

The agroecological conditions for maize production are different in the various regions of Serbia. The application of appropriate growing practices mitigates adverse effects of climate and soil and provides conditions for the maximum utilisation of the genetic yielding potential of maize hybrids under particular agroecological conditions. The application of a system of measures that encompasses proper crop rotation (eg. the use of soybean as a preceding crop, the avoidance of sugar beat and monoculture), primary soil tillage (on depth of 20-30 cm), fertilisation (application of a complete amount of potassium and phosphorus in autumn, and nitrogen in a presowing time), sowing (the use of only certified seed, and early sowing in case of drought), installation of irrigation systems (the adjusted irrigation norms in respect to monthly needs of maize), weed control (development of the system of combined preventive measures, inluding crop cultivation), as well as timely harvest provides favourable conditions for the corect development of maize crop, which are the basic prerequisites to reduce the impact of natural hazards and to obtain high and stable yields. Growing cover crops and intercropping as well as the use of mulch, can positively affect plant development, water-air properties and soil fertility and protection of maize from pests. The selection of hybrid to be cultivated must be based on the agroecological conditions in the regions. In areas with less precipitation, hybrids of earlier FAO maturity groups (300–500) should be cultivated. Neglecting the mentioned requirements in terms of agricultural practices or reducing certain measures will inevitably lead to yield losses.


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The Serbian Ministry of Agriculture, Forestry and Water Management (MARW) is keen to increase the preparedness of maize producers to counteract the effects of natural hazards. Therefore, MARW has requested FAO to facilitate the writing of a technical guideline on good practices and technologies to reduce the impact of natural hazards. A workshop brought Serbian experts together to discuss the current knowledge on the impact of natural hazards on maize production in Serbia, and identify good practices and innovative technologies that could help to reduce the impacts of natural hazards.

With climate change, it is expected that natural hazards, such as floods, droughts, storms, will increase in frequency and severity. Agriculture is one of the most climate sensitive sectors. Natural hazards may cause the yield reductions or even total crop failure. In this brochure are described good agricultural practices and technologies to reduce the impact of natural hazards in maize production in Serbia, related to crop rotation, soil tillage, subsoiling, mulching, growing cover crops, selection of hybrids, sowing, intercropping, fertilization, weed and pest control, irrigation/drainage, ensiling and harvesting. The brochure is intended for maize producers, ministries and entities of Republic of Serbia, civil society, researchers/academics, agricultural extention services, and agricultural organizations. The brochure has been developed as one of the outputs of the FAO project *'Enhancement of Disaster Risk Reduction and Management (DRRM) capacities and mainstreaming Climate Change Adaptation (CCA) ppractices into the Agricultural Sector in the Western Balkans' (TCP/RER/3504).*

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