SOME ASPECTS OF CULTIVATION AND UTILIZATION OF WAXY MAIZE
(Zea mays L. ssp. ceratina)

Agnieszka Klimek-Kopyra, Aleksander Szmigiel, Tadeusz Zając, Agnieszka Kidacka

1Institute of Plant Production, Department of Plant Production, University of Agriculture in Kraków
Mickiewicza 21, 31-120 Kraków, Poland
2Małopolska Hodowla Roślin HBP-Sp.z.o.o, Zbożowa 4, 30-002 Kraków.
e-mail: aklimek@ur.krakow.pl

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INTRODUCTION

This paper is a review. In our region, there is marginal interest in the cultivation and utilization of Zea mays ssp. ceratina grain. Numerous data presented in particular sections of this paper relate to the origin, history of cultivation, grain properties, agronomy as well as the use of maize raw material in industry and for animal feed production.

Maize played an enormous role in the ancient civilisations of the New World from the oldest times. This cereal was grown across the whole American continent down to the present Argentina and Chile. It appeared quite soon afterwards in Europe, Africa and Asia (Nowiński, 1970). Maize reached Poland much later (19th century) and was known under the name of “Turkish wheat” (Felisiak, 1987). In the regions of Wielkopolska (Greater Poland) and Małopolska (Lesser Poland), green maize was originally harvested, whereas grain maize was grown in gardens. A new era in maize cultivation began after Mikołowski-Pomorski, Górski and Golonka had introduced new more productive varieties. However, a true breakthrough in maize breeding occurred in the middle of the 1950’s as a result of the use of the heterosis effect (Gąsiorewski, 2005, 2006, 2008). Currently, maize is one of the three most important agricultural plant species in the world, alongside wheat and rice. As an annual plant, it is mostly grown for grain which is used for the production of flour, animal feed and ethanol. Grain production per unit area has been growing systematically; it increased from 1.9 t × ha⁻¹ in 1960 up to 5.1 t × ha⁻¹ in 2008. A major part of maize grain is used as livestock feed.
in the form of cracked maize but, as reported by Nociek and Tamminga (1991), there are limitations in using maize for livestock feeding due to its low protein and vitamin content.

Among the subspecies compared, Zea mays ssp. indurata and Z. mays ssp. indentata are of the greatest importance (Michalski, 1997). The significance of the subspecies Zea mays ssp. saccharata in growing maize is much smaller, while Z. mays ssp. ceratina has a marginal role (Collins, 1909, 1920; Waligóra et al. 1998). The first reports about the occurrence and cultivation of waxy maize in China come from 1909 (Collins, 1909).

A decision to grow a particular maize subspecies involves many aspects and is based on specific climatic and soil conditions, tradition and consumer needs as well as on the market for maize raw material. Sweet corn is more and more frequently promoted as a vegetable product and also as raw material for the processing industry (Waligóra et al. 1998). In Poland sweet corn is grown on an area of not more than 4,000 ha, which is associated with its low consumption, since sweet corn consumption remains at a level of 0.5 kg/person (Waligóra, 2006). Waxy maize (Z. mays ssp. ceratina) is even less popular in Europe; it differs from other subspecies by the unique structure of its starch due to a reduced percentage of the amylose fraction and an increased percentage of amyllopectin. In nutritional terms, the composition of the waxy maize grain is similar to that of other subspecies of Z. mays, which is associated with, among others, a low amount of protein (9%) (Zarate et al. 2004). 200,000 tonnes of waxy maize grain is now produced in Europe, mainly in France. In this country, the average annual acreage is 30,000 ha in the southern and northern regions, out of the total crop area of 1.5 million hectares (Boeck et al. 2002). Waxy maize production in Europe accounts for not more than 2% of the total maize crop area and the utilization of waxy maize depends on the quality of raw material obtained. Waxy maize grain is thought to be an interesting alternative to hybrid maize if it is used for industrial purposes, i.e. the recovery of starch and its processing into particular substances or for modified starch production. The grain of this species is mostly intended for industrial use, though it can also be used as animal fodder to feed poultry (Mussehl, 1944; Dinn et al. 1982), pigs (Johnston and Anderson, 1992; Ertl and Dale, 1997), and cattle (Akay and Jackson, 2001). However, the current scale of waxy maize cultivation is relatively small, which nowadays is translated into its small economic importance.

It is thought that total maize grain production will be one of the largest in Europe in the near future due to the developing starch and biofuel industries. Assuming that the agricultural policy of the below mentioned states does not change until 2020, maize grain production in the USA will be 297 million tonnes, 295 million tonnes in China, and 54 million tonnes in Brazil, whereas the Eastern Europe countries will reach a total production of 40 million tonnes.

The need, widespread in recent years, to improve the nutritional values of maize grain as a major cereal in Asian countries has not resulted in an increased amount of protein in the grain composition. Hence, common protein deficiency and protein-calorie malnutrition in people can be observed in many regions in the world where maize is the main source of food. Attempts have now been undertaken in plant breeding to improve maize varieties in terms of their quality related to a higher percentage of protein in the grain, including endogenous amino acids – lysine and tryptophan (Og et al. 1993; Dang, 2010). In Asia the cultivation of waxy maize is promoted to increase human food production, while the leading subspecies producing ‘flint’ or ‘dent’ kernels are now the primary source of livestock feed (silage and cracked maize). Its high carbohydrate content and relatively long storage period predispose it for such purposes.

THE ORIGIN AND CHARACTERISTICS OF WAXY MAIZE

The original form of waxy maize had erect leaves growing from the upper nodes, while the lower leaves were spread and drooping (Collins, 1909). Moreover, the leaves up to the 4th-5th leaf from the bottom grew on the same side of the plant. The above-mentioned author stressed high drought resistance of maize, in particular at the flowering stage, and waxy maize was positively distinguished from other Z. mays subspecies by this trait.

The basis of phenotypic selection of maize was applied as early as 1900 in China, which is described by Collins (1909). The characteristics of waxy maize given by Collins were based on an analysis of the morphological characters associated with plant growth. It was discovered much later, as late as the 1990’s, that the characteristic features of the endosperm in maize were controlled by a single recessive gene found in chromosome 9 which was described and named waxy (wx) or china waxy (wx-c), due to the region of its origin. Coe et al. (1988) described the characteristic phenotypic features of the grain as marbled, opaque and hard. The endosperm of waxy maize develops only branched starch molecules (amylopectin) which are devoid of the linear fraction. The next unique feature of starch in this subspecies is the expansion reaction taking place as a result of treatment with iodine solution (Weatherwa x, 1922). When treated with potassium iodide, amylopectin of waxy maize stains
Some aspects of cultivation and utilization of waxy maize (*Zea mays* L. ssp. *ceratina*)

red and brown, whereas normal starch turns blue and black. Waxy maize from the area of Argentina (*wx-a*), described by Andrés and Bassioli (1941), is known to produce grains containing a small amount of amylose (<5%), which gives an immediate reaction with iodine. Other mutants found within this subspecies are similar to those previously described (Bear, 1944; Nelson, 1968).

During the period from 1930 to 1990, waxy maize was grown sporadically for production purposes and researchers concentrated more on breeding experiments. In the 1940’s at the Agricultural Experimental Station in Iowa (USA), further and, at the same time, important properties of amylopectin of waxy maize were discovered which are similar to those found in tapioca (*Manihot utilissima*) (Schopmeyer et al. 1943). Due to the fact that it was not possible to import tapioca from eastern Asia during World War II, there was a breakthrough in the use of waxy maize starch for industrial purposes. The U.S. government launched a special research programme designed to implement the starch of this subspecies into different industries. Thus, research was carried out in the state of Iowa which was aimed at improving the chemical properties of maize grain in order to process this grain only for industrial purposes. Currently, breeding programmes are still being developed in the USA and they are designed to improve the genetic line of waxy maize with regard to its yield-enhancing traits. Fergason (2001) indicates that waxy maize varieties are now equal in yield to ‘dent’ field corn, and average variations in yield do not exceed 5%. But a real breakthrough in the process of selection of new varieties over the last 20 years has been observed in China. In this country, scientists have undertaken a number of studies to improve grain quality, including an increase in embryo weight, in order to enhance the processing capacity of the vegetable oil and starch industries (Ding et al. 2006). As a result of that, both high oil corn (HOC) and high oil waxy corn (HOWC) have been bred (Table 1).

<table>
<thead>
<tr>
<th>Chemical component</th>
<th>Normal corn</th>
<th>High oil corn</th>
<th>Waxy corn</th>
<th>High oil waxy corn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry matter</td>
<td>85.92</td>
<td>87.06</td>
<td>89.31</td>
<td>89.43</td>
</tr>
<tr>
<td>Crude oil</td>
<td>3.66</td>
<td>7.51</td>
<td>4.62</td>
<td>8.22</td>
</tr>
<tr>
<td>Crude protein</td>
<td>7.37</td>
<td>8.33</td>
<td>8.97</td>
<td>9.77</td>
</tr>
<tr>
<td>Starch</td>
<td>62.9</td>
<td>-</td>
<td>68.5</td>
<td>-</td>
</tr>
<tr>
<td>ME Kcal/kg</td>
<td>3314</td>
<td>3540</td>
<td>3494</td>
<td>3650</td>
</tr>
</tbody>
</table>

Source: Akay and Jackson, 2001; Zarate et al. 2004.

Starch, as a complex carbohydrate, belongs to the group of the most important plant products, extremely essential in animal and human nutrition (Burrell, 2003). Cereal grains are the main source of starch and partially it can be also obtained from roots and tubers. It is estimated that every year cereal plants can produce 2050 million tonnes of starch, whereas roots and tubers supply only 679 million tonnes of this component (Tester and Karkalas, 2001). In developed countries, starch supplies on average 35% of the daily caloric requirement for humans. Maize, rice and wheat grain as well as potato tubers are the main plant sources of this component. In many areas of the world, in particular in the continent of Africa and in the Far East, starch supplied as food from rice grain currently accounts for up to 80% of the daily caloric requirement for humans.

One should stress the fact that starch has been used for food and non-food purposes for centuries, since already the ancient Egyptians and later Romans used this component as an adhesive (glue), while the Greeks used it as a medicine (Tester and Karkalas, 2002; Burrell, 2003). In chemical terms, starch is composed of amylose and amylopectin. Amylose has long -1,4 chains linking the glucose residues and a relatively small number of branched -1,6 bonds, whereas amylopectin contains a high number of branched -1,6 bonds and a small number of branched -1,4 bonds linking the glucose residues. These two molecules produce the semi-crystalline form of starch (Banks and Muir, 1980; Kainuma, 1988). The average size of starch grains ranges from 0.5 to 170 μm (Golachowski, 1998). Among cereal plants, normal maize has the largest average size of starch grains (5-25 μm), whereas in the kernel of waxy maize the average size of starch grains is in the range of 4-28 μm (Lewandowicz and Mačzyński, 1990). The size of starch grain is of major importance for industrial use, since it determines the physico-chemical properties of a particular starch (Ratusznia and Kubas, 2007). Maltodextrin and starch are an important source of energy for small children due to the low propensity of this type of food to fermentation. It is estimated that about 70% of food products now contain corn syrup in its composition (Tester and
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Waxy maize starch is an important ingredient in the preparation of various meat products and ready-made meat dishes.

THE EFFECT OF CULTIVATION ON BIOLOGICAL CHARACTERS AND YIELD

The growing interest in waxy maize cultivation across the world, due to the ever higher demand for starch in the food and processing industries, has contributed to the development of agronomic research. Fertilization and seeding rate are the factors that limit waxy maize yield. Depending on the plant growth stage, the absorptive ability of cultivars and habitat conditions, different fertilization rates can be used in growing waxy maize (Weir et al. 1996). Piekiełek and Fox (1992) report that the maximum daily nitrogen intake 30-45 days after emergence (at silking stage) is 4.43 kg × ha⁻¹d⁻¹. Boonlertnirun et al. (2010a) compared three waxy maize cultivars and found the average plant height to be 160 cm. These authors showed that fertilization rates did not differentiate the growth of these cultivars, but the rate of nitrogen at a level of 250 kg N × ha⁻¹ was economically justified. Different results were obtained in the study of Boonlertnirun et al. (2008) who found that the application of increasing rates of nitrogen resulted in significant differences in plant dry weight per unit area. These authors proved that significantly higher dry weight per plant (90g × plant⁻¹) could be obtained after the application of nitrogen at a rate from 75 to 225 kg × ha⁻¹, but the higher rates were not economically justified. Such results were also observed in other cereal plants in which an increase in nitrogen fertilization also affected the growth of the aerial parts (Balasubramanian and Singh, 1982).

Moreover, Boonlertnirun et al. (2010b) showed that nitrogen fertilization of waxy maize at a rate of 75-225 kg N × ha⁻¹ had a highly significant effect on increasing leaf area of waxy maize plants. In this study, the maximum leaf area per plant was found to be at a level of 4,253 cm², while the minimum value of this parameter was 1,640 cm² × plant⁻¹.

Oiken et al. (1998) and Amany et al. (2006) showed that nitrogen fertilization of waxy maize at a rate of 75-225 kg N × ha⁻¹ had a highly significant effect on leaf area of waxy maize plants. In this study, the maximum leaf area per plant was found to be at a level of 4,253 cm², while the minimum value of this parameter was 1,640 cm² × plant⁻¹.

Chen et al. (2003) found waxy maize grain yield to be significantly dependent not only on nitrogen fertilization, but they claimed that plant density was also important. The results of their study showed that higher than average grain yield was obtained at a plant density of 60,000 plants per hectare and

### Table 2

Waxy maize cultivation regions and nitrogen rates applied.

<table>
<thead>
<tr>
<th>Region</th>
<th>Rate N (kg × ha⁻¹)</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Italy</td>
<td>150-240</td>
<td>Blandino and Reyneri, 2007</td>
</tr>
<tr>
<td>Denmark</td>
<td>140</td>
<td>Eggum et al. 1985</td>
</tr>
<tr>
<td>Thailand</td>
<td>300</td>
<td>Boonlertnirun et al. 2010a</td>
</tr>
<tr>
<td>China</td>
<td>250-420</td>
<td>Xie, 2006</td>
</tr>
<tr>
<td>USA</td>
<td>140-180</td>
<td>Brookes and Barfoot, 2004</td>
</tr>
<tr>
<td>Argentina</td>
<td>175-300</td>
<td>Valero et al. 2005</td>
</tr>
</tbody>
</table>
a fertilization rate of 225.5 kg N × ha⁻¹. Similar results were obtained by Zhao et al. (2009) who emphasize that maximum foliage parameters, as expressed by LAD, LAI and dry weight per ha, could be obtained in a crop with a density of 60,000 plants × ha⁻¹. Jin et al. (2010) report that, in productive terms, the most appropriate plant density is 90,000 plants × ha⁻¹ and above this value grain yield declines.

Tang et al. (2009) compared the proportion of particular components of the above-ground biomass of normal and waxy maize during growth. These authors confirmed the earlier reports of Toledo and Sundstol (1999) which show that during vegetative growth the amount of dry matter changes between different plant parts. At fill grain (milk stage), the stem part had the highest percentage in total shoot dry weight, while flag leaves and sheathing leaves of cobs had a smaller percentage. It was also interesting that during growth the percentage of leaves (leaf blade and leaf sheath) of Z. mays ssp. ceratina in total shoot weight increased, while the percentage of stems decreased. In waxy maize, the percentages of the investigated fractions were as follows: leaf blades (LB)-25.9%; leaf sheaths (LS)-14%; stem (ST)-41.1%; husks (HK)-19%; and they were similar to the proportions of these fractions in field corn, for which the respective values were the following: LB-27.2; LS-14.3; ST-36.7; HK-21.8%. The present study showed significant differences in total protein content. The protein content (g × kg⁻¹DW) in the above-ground mass of waxy maize was proved to be significantly higher compared to field corn, since in the plant parts in question its values were as follows: LB-160; LS-55; ST-62; HK-50, whereas in the conventional form: LB-56; LS-50; ST-53; HK-50. The results for crude fibre content were opposite, which is confirmed by Ackay and Jackson (2001). It is stressed that the higher protein content and lower fibre content in animal feed result in better digestibility of waxy maize silage (Mustafa et al. 2008). However, Tang et al. (2008, 2009) think that the higher nitrogen content in waxy maize can result from the higher sorptive capacity of the root system, which is translated into an increase in the amount of protein in leaves and stems.

Sowing date has a significant effect on grain quality. Studying the effect of sowing date (in the period from the 3rd decade of April until the 2nd decade of May) on maize yield, Liu et al. (2009) showed significant differences in the quality of harvested grain. These authors found that the late sowing date (the 2nd decade of May) negatively influenced the amount of starch, protein and oil obtained. The decrease in the quantitative and qualitative parameters of grain yield was associated with lower total rainfall available to the plants during growth.

WAXY MAIZE AS INDUSTRIAL RAW MATERIAL

Waxy maize was originally used mainly for industrial production and only to a small extent for food production (Moore et al. 1984; Hawton et al. 1996). Jugenheimer (1976) set out the scope of industrial use of waxy maize as more important for economic development. Among many uses of maize grain, this author mentioned the use of maize starch in the vegetable oil, chemical and textile industries as well as for the production of plastics. In Asia, there is currently a growing interest in waxy maize for the food industry and for the production of biogas intended for nitrogen fertilizer production (Tang et al. 2011).

The production of biomass in Z. mays ssp. ceratina is controlled by a single recessive gene, therefore grain quality is determined primarily by the genetic purity of seed material. It is thought that maize grain production on an industrial scale requires the observance of the principles related to spatial isolation of crops in order to protect them against self-crossing of various subspecies (Brink and Macgillnra, 1924). Furthermore, waxy maize grain for industrial purposes should have high quality as well as large and well-formed kernels of full health and purity (99%). Grain uniformity is also important, including its size and colour. In North America, waxy maize grain production is strictly controlled and contracted in terms of its intended use for the milling and starch industries. Starch extraction from maize grain is the first stage towards versatile modification. Starch modification is used in the food, confectionery, and milk industries as well as for storage of food products (Moore et al. 1984). The paper industry also owes its great progress to the implementation of modified starch of Z. mays ssp. ceratina. Waxy maize starch has contributed to an improvement in the process of binding of paper material, which has had an effect on printing quality. Modified starch has also contributed to the development of the textile industry (Kirby, 1986). Starch obtained from waxy maize is used very frequently in starch-producing plants, as a result of wet grinding. Grains used for this purpose should contain a large amount of starch, which is associated with the absence of damage of the cell structure during harvest. Slight differences in the amount of starch can affect the quality of laundry starch obtained. The unique properties of starch, compared to flint or dent maize, are an attribute for its production and processing.

Most of natural starch obtained has specific and limiting physical and chemical properties, which gives rise to a number of technological problems. Industrial utilization of starch is associated with the need to carry out many expensive repression processes in order to give proper physical properties to starch. Waxy maize
belongs to the class of special purpose maize, characterized by a unique structure of starch, which creates enormous possibilities for its modification (Fergason, 2001). Chemical modifications include crosslinking associated with the introduction of additional cross links into the chemical structure of starch, the effect of which is greater resistance to thermal conditions, pH (Kryśniska et al. 2008). Such modified starch is used to improve the texture of pastas and fruit fillings for cakes (Walkowski and Lewandowicz, 2004). On the other hand, double modified starch is commonly used for the production of sauces, tinned vegetables and meat, frozen products and desserts (Leszczyński, 2006). In his paper, Young (1984) presents as many as 30 processing areas in which this raw material can be used. Waxy maize grain is used in the food industry (Moore et al. 1984; Langman, 1986), paper industry (Maher and Cremer, 1993), and textile industry (Kirby, 1986) as well as for other industrial purposes (Rohwer and Klem, 1984).

THE USE OF WAXY MAIZE AS ANIMAL FEED

The dynamic development of livestock farming and the creation of new waxy maize varieties (in the USA and in Asia) have increased the potential possibilities of using this species for animal feed purposes. Johnston and Anderson (1992) proved that the chemical composition of the grain of waxy maize could contribute to greater use of this fodder material in feeding slaughter cattle. Schroeder et al. (1996) indicate the fact that waxy maize grain is as good as normal maize grain in feeding dairy cattle. However, the proportion of grain in livestock feed is of great importance for the use of waxy maize. The complete replacement of dent maize with waxy maize did not result in significant differences in the amount of milk obtained and in changes in its composition. As a result of applying a 50% proportion of each type of maize grain, a decline in the amount of milk fat was recorded, which may prove the adverse interaction in the use of these two types of starch by an animal. According to Huntington (1997), variation in nutritional needs of cattle is an attribute for changes in the composition of the endosperm in maize. Banks and Muir (1980) as well as Brown et al. (2001) showed that amylopectin accounted for nearly 95% of starch in waxy maize, whereas in normal dent maize the percentage of amylopectin is at a level of 73%. Additionally, starch granules of waxy maize have higher hydrolytic ability, hence fodder from waxy maize was expected to have higher digestibility (Kimura and Robyt, 1995). Digestibility evaluated for waxy maize can change the character of fermentation in the rumen (Braman et al. 1973; Streeter et al. 1991; Kotarski et al. 1992) and also affect the quality and quantity of milk (Nocek and Tramminga, 1991). Kotarski et al. (1992) report that starch from waxy maize is more digestible and its structure with protein has a greater ability to degrade during technological processes. Maize grain is also a basic source of energy in poultry feeding. Collins et al. (2003) carried out a comparative study on the effect of the properties of grain of two maize subspecies on the weight of poultry meat and its quality. The authors proved that feeding young chicks with waxy maize grain was more efficient than feeding them with traditional dent maize. It is worth paying attention that better digestibility of starch for dairy cattle is not an advantage at all, since digestible starch is sought as far as the duodenum (by-pass starch).

Tang et al. (2009) conclude that the nutritional value of waxy maize is dependent not only on climatic conditions and proper agricultural practices, but also on the morphotype. Tolera and Sundstol (1999) as well as Tang et al. (2008) report that total protein content was significantly higher in the leaves, and lower in the stems. Moreover, the nutritional value of waxy maize is also affected by plant growth stage and sowing date. A delayed date of maize harvest had an effect on a lower weight of leaves and stems, a lower amount of protein and phosphorus as well as a higher quantity of fibre. Conventional maize varieties had a lower amount of total protein and a higher amount of fibre in the kernel compared to sweet, waxy and field corn (Tolera and Sundstol, 1999).

Table 3

<table>
<thead>
<tr>
<th>Maize subspecies</th>
<th>Protein</th>
<th>Oil</th>
<th>Fibre</th>
<th>Starch</th>
<th>Yield t × ha⁻¹</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waxy</td>
<td>9.1</td>
<td>4.5</td>
<td>2.2</td>
<td>73.2</td>
<td>9.33</td>
<td>Fergason, 2001</td>
</tr>
<tr>
<td>Sweet</td>
<td>3.3</td>
<td>1.9</td>
<td>1.4</td>
<td>5.7</td>
<td>4.00</td>
<td>Waligóra, 1998</td>
</tr>
<tr>
<td>Normal traditional variety</td>
<td>9.9</td>
<td>4.6</td>
<td>2.1</td>
<td>71.6</td>
<td>11.2</td>
<td>Aleksander, 1988</td>
</tr>
<tr>
<td>Normal high-oil variety</td>
<td>8.3</td>
<td>7.6</td>
<td>2.9</td>
<td>67.9</td>
<td>11.9</td>
<td>Aleksander, 1988</td>
</tr>
<tr>
<td>Normal high-protein variety</td>
<td>12</td>
<td>5.0</td>
<td>2.1</td>
<td>58</td>
<td>5.97</td>
<td>Vasal, 2001</td>
</tr>
</tbody>
</table>
Waxy maize contains an increased amount of protein and oil, but less than the high-oil variety. Most of these differences are a result of changes in the size of the embryo in the grain, up to the endosperm.

SUMMARY

Based on FAO forecasts, it is expected that there will be a significant global increase in demand for industrial maize grain over the next 20 years. The global demand for maize grain results from the higher demand for starch in the world market and to a lesser extent from the demand for grain for consumption, which can be observed in particular in the USA and Asia. In Europe the higher demand for starch will be met through the increased proportion of high-starch varieties in the general structure of maize crops. However, starch from grain has limited modification properties due to its biochemical structure. A result of this is the extension of technological processes designed to give proper physico-chemical properties to starch. Waxy maize is characterized by a unique structure of starch, which allows a simplified process of its modification and gives wide possibilities of industrial use. New sources of variation are now sought, relating to increased embryo weight in the kernel, which will increase oil yield per hectare. An increased proportion of glassy endosperm in the grain will be translated into a significant increase in protein, which is important for the milling industry. A higher percentage of the floury endosperm fraction in the kernel will contribute to increased starch content, essential for ethanol production. For these reasons, waxy maize has become an important source of starch in the region of Asia, America and Africa, but it is still marginalized in Europe. In Poland relevant research has not been hitherto undertaken and varieties of this subspecies have not been introduced into cultivation. Therefore, an urgent research task is to evaluate, under domestic conditions, varieties of *Z. mays ssp. ceratina* as well as their yield and chemical composition. It can be presumed that the development of the starch industry, associated with the demand for industrial starch, will contribute in the near future to increased interest in waxy maize in our country. Waxy maize grain, which is an interesting alternative for the starch industry, can compete with normal maize grain and contribute to the development of the cultivation of this subspecies.

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Wybrane aspekty uprawy i użytkowania kukurydzy woskowej (Zea mays L. ssp. ceratina)

Streszczenie

Praca stanowi przegląd dostępnej literatury dotyczącej Zea mays L. ssp. ceratina. Zawiera informacje na temat pochodzenia uprawy i wykorzystania kukurydzy woskowej w świecie i może być przyczyną do rozwoju nowych badań z zakresu uprawy i technologii przetwórstwa skrobi.


Dużym atutem kukurydzy woskowej jest specyficzna budowa skrobi, z uwagi na unikatową i wysoką zawartość amylopektyny (95-98%), co nadaje nieograniczone możliwości wykorzystania przemysłowego. Obecnie areal kukurydzy woskowej w Europie nie przekracza 2% powierzchni zasiewów kukurydzy na kontynencie.