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Review

Sweet Corn Research around the World 2015–2020

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Abstract: Modern sweet corn is distinguished from other vegetable corns by the presence of one or more recessive alleles within the maize endosperm starch synthesis pathway. This results in reduced starch content and increased sugar concentration when consumed fresh. Fresh sweet corn originated in the USA and has since been introduced in countries around the World with increasing popularity as a favored vegetable choice. Several reviews have been published recently on endosperm genetics, breeding, and physiology that focus on the basic biology and uses in the US. However, new questions concerning sustainability, environmental care, and climate change, along with the introduction of sweet corn in other countries have produced a variety of new uses and research activities. This review is a summary of the sweet corn research published during the five years preceding 2021.

Keywords: sweet corn; breeding; stress; pests; nutrition; quality

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1. Introduction

Modern sweet corn depends on various altered alleles that disrupt endosperm starch synthesis which increase sugar content and alter polysaccharide composition [1,2]. Consequently, such changes are often the result of loss of function alleles. Some of these alleles lead to lead to potential problems in germination and emergence, especially in unfavorable environments. The genetic base of the temperate sweet corn germplasm is narrow due to a number of genetic bottlenecks during its evolution and largely based on the maize race "Northern Flint" [1–3]. First Nations people created Northern Flint by adapting corns from the region that now encompasses north-western Mexico and southwestern USA to north-eastern North America, a region with very different climatic conditions. Due to its extreme isolation, Northern Flints are generally more susceptible to foreign diseases and insects. European colonizers originally grew sweet corn with white (Y1Y1) endosperm. A second significant bottleneck occurred with the introduction of the cultivar "Golden Bantam". Golden Bantam's yellow endosperm proved very popular and became the new standard. Many of the white endosperm cultivars were then crossed to Golden Bantam and converted to yellow. Most early public sweet corn inbreds were derived from the aforementioned populations.

The narrow genetic basis and defective endosperm mutants become serious limitations in modern agriculture with increased social demands for healthier, safer production practices that rely less on the use of synthetic chemicals. The agronomic limitations of temperate sweet corn, namely poor emergence and early vigor, affect production at large, especially pest management as well as abiotic stresses including soil fertility, temperature and water stress. Essentially all aspects of sweet corn production are affected by the natural limitations, altered endosperm alleles, and genetic background.

Sweet corn reviews have been published on endosperm genetics, breeding, and physiology that focus on the basic biology and uses in the US. However, new questions concerning sustainability, environmental care, and climate change, along with the introduction of sweet corn in other countries has produced a variety of new uses and research activities. This review looks at sweet corn research from 2015 to 2020 in multiple areas as they relate to genetics, biotic and abiotic pressures, production, uses and dietary value.

2. Genetics and Breeding

2.1. Genetic Basis of Modern Sweet Corn

Corn growing people have always eaten green (fresh) corn harvested at the "milk stage", roughly 20 days after pollination (DAP) when the kernels have a high moisture content (>70%). Unlike other maize, modern sweet corn contains one or more alleles that disrupt endosperm starch synthesis, increasing sugar content and altering levels of polysaccharides. First Nations peoples throughout what is now the Americas grew corn with the *sugary1* (*su1*) allele and may have eaten it fresh, but some report that *su1* corn was usually harvested dry for confectionary purposes. [4].

While a narrow genetic base is a major constraint in sweet corn breeding for the USA, it becomes an even greater limitation when breeding for non-native environments. Several researchers have evaluated the available genetic variation in their target environments. For plant breeders, the classical method of evaluating genetic diversity is calculating combining ability. Pacurar et al. [5] analyzed sweet corn inbreds from Romania for variability of biochemical components: protein, starch, sugar, neutral detergent fiber, and neutral cellulose digestibility. There was wide variability among inbred lines for sugar content. Elayaraja et al. [6] assessed the combining ability of 60 line x tester hybrids from 20 female sweet corn parents with three tester sweet corn cultivars. General and specific combining ability were significant for all traits indicating that both additive and dominance variance were operating. They also identified some promising combinations. Suzukawa et al. [7] investigated general and specific combining ability for grain yield and soluble solid contents of seven lines of sweet corn (*su1*) and eight supersweet (*shrunken2*) corn lines adapted to Brazil and identified some potential parents for commercial sweet corn hybrids.

Goncalves et al. [8] investigated the relative importance of agronomic traits in the supersweet corn developed in Brazil in order to develop strategies able to improve efficiency in selection of superior genotypes. Ear diameter and ear length had the highest contribution to ear yield. Number of kernels per ear had the greatest variation among hybrids. Khan et al. [9] studied characteristics of sweet corn landraces under different planting conditions in Pakistan. They reported planting date effects on most agronomic traits, and genetic variability for several traits, such as cob diameter, kernel length, kernel width, and number of kernel rows.

Molecular markers allow a deeper knowledge of germplasm collections. Relatedness based on genome-wide single nucleotide polymorphisms among diverse inbreds provide valuable information for breeding and germplasm management in crops. Maize in toto has a large and complex genome and, despite numerous bottlenecks during the development of temperate sweet corn, there remains significant genetic variability. Yang et al. [10] developed a visualization pipeline based on publicly available molecular markers from current important maize inbred lines, including temperate, tropical, sweet corn, and popcorn. The detailed relatedness revealed the genetic diversity among these inbreds, which was consistent with several previous reports, indicating that that the tree is reliable and could potentially speed up advances in crop breeding. Ferreira et al. [11] evaluated the genetic diversity of 12 elite lines of sweet corn, using 20 microsatellite markers and concluded that the high genetic diversity detected would allow the selection of promising divergent sweet corn genotypes. Mehta et al. [12] analyzed 48 diverse sweet corn genotypes from *su1su1*, *sh2sh2*, and *su1su1/sh2sh2* types using 56 microsatellite markers. They identified inbreds for synthesis of pools and populations to develop novel inbreds and prospective heterotic combinations in various genetic backgrounds (*sh2sh2 x sh2sh2*, *su1su1 x su1su1*, *su1su1/sh2sh2* x *su1su1/sh2sh2*, *sh2sh2* x *su1su1/sh2sh2* and *su1su1 x su1su1/sh2sh2*). For maize-breeding programs in Korea, Ko et al. [13] compared the efficiency of simple sequence repeat (SSR) and sequence specific amplified polymorphism (SSAP) markers for analyzing genetic diversity, genetic relationships, and population structure of 87 supersweet corn inbred lines from different origins. Even though supersweet corn has a narrow genetic origin and is not widely used in Korea; they found enough variability for breeding supersweet for Korea.

Combinations of molecular markers and phenotypic data have been used for classifying sweet corn genotypes. Mahato et al. [14] assessed genetic diversity among 39 sweet corn inbred lines on the basis of 14 agro-morphological traits, two quality parameters and 63 microsatellite markers, selected on the basis of their association with quantitative trait loci (QTL) affecting kernel quality. The authors identified inbreds with high yield and sugar content as likely parents of high-yielding hybrids of improved quality. Dermail et al. [15] used genetic models for choosing appropriate parents for sweet corn hybrids. They determined combining ability and heterosis among 24 hybrids, genetic relationships among 11 parental lines based on SSR markers and studied the association between SSR based-genetic distance and hybrid performance. They found high heterosis lacking specific combining ability (SCA) effects, wide SSR based-genetic distance among sweet and waxy lines, poor correlations between SSR and heterosis and, therefore, poor prediction ability of hybrid performance based on genetic distance. More explicitly, Bonchev et al. [16] investigated the retrotransposon-related genetic distances among parental inbred lines and hybrid performance in 15 maize inbreds representative of the genetic diversity among sweet corn and field corn lines. Genetic distance and heterosis, averaged over inbred lines, were weakly correlated. Phenotypic distances negatively correlated with heterosis for ear height, ear diameter, and number of kernel rows per ear. Zystro et al. [17–19] generated 100 sugary enhancer (se1) sweet corn hybrids from four 5×5 North Carolina Design II mating blocks. They grew the hybrids alongside their 40 inbred parents, in multi-location organic trials in 2015 and 2016. The phenotypic data from the trials were used in concert with rich marker data to predict the performance of untested hybrids and synthetic varieties. Untested hybrids and synthetic varieties were grown in five organic environments in 2017. In general, the use of genomic prediction models slightly increased the accuracy of predictions of hybrid performance above the predictions based solely on general combining ability. However, the addition of dominance effects did not generally improve the predictions.

2.2. Genetic Modification

Though sweet corn mutants are naturally obtained through spontaneous mutation, genetic modification methods are also used for generating some alleles that are lacking in natural collections, though genetically modified organisms are rejected in several countries. Anderson et al. [20] studied the expression and safety of genetically modified sweet corn with overexpression of the ZMM28 protein, which results in maize plants with increased plant growth, photosynthetic capacity, and nitrogen utilization and concluded that additional studies are needed to assess food and feed safety of the DP202216 maize event. Reddy et al. [21] reported that glyphosate resistance technology has minimal or no effect on maize mineral content and yield. Likewise, Williams et al. [22] determined that incidence of Goss' wilt *Clavibacter michiganensis* subsp. *nebraskensis*) sweet corn is independent of transgenic traits and glyphosate use. Kelliher et al. [23] used the process of CRISPR-Cas9 with haploid induction to induce edits in nascent seeds of diverse crops. That method enables direct genomic modification of commercial varieties. The authors tested the Haploid inducer-Edit method in field and sweet corn using a native haploid-inducer line and recovered edited wheat embryos delivered by maize pollen. Edited plants could be included in commercial variety development.

Some plant viruses have been used as vectors for foreign gene expression and virus-induced gene silencing. Among these viruses, the tripartite viruses Brome mosaic virus and Cucumber mosaic virus have been used to induce gene silencing in maize. Mei et al. [24] describe a new DNA-based virus-induced gene silencing system derived from Foxtail mosaic virus (FoMV). Four genes, *phytoene desaturase* (*y1*), *lesion mimic22*, *iojap* (*ij1*), and *brown midrib3* (*bm3*), were silenced and characterized in the sweet corn cultivar Golden Bantam. They demonstrate that the FoMV infectious clone establishes systemic infection in maize inbred lines and other crops. In the US, transgenic sweet corn is available. It has been engineered to be resistant to some insects and damage by certain classes of herbicides [25]. In the USA, transgenic sweet corn hybrids are used only in the fresh market but not commercial sweet corn processing. A large majority of USA fresh market sweet corn hybrids are non-transgenic.

2.3. Endosperm Loci That Affect Quality

The alleles that sweet corn relies on for good table quality generally have detrimental effects on seed viability. This has been investigated in the classical sweet corn mutant *su1* by several authors. Allam et al. [26] estimated fitness of the *su1* mutant in diverse environments and genetic backgrounds and found that viability of *su1* is under genetic and environmental controls, regulated by multiple genes with minor contributions. These results have implications for mutagenesis breeding or genome editing because the epistatic effects of the target genome on the new alleles could affect the success of their in-breeding programs.

Wild-type *Su1* encodes the starch debranching enzyme isoamylase1 required for amylopectin production. Shuler et al. [27] characterized five naturally occurring *su1* mutations with different carbohydrate compositions. Significant differences in carbohydrate composition were identified among the *su1* alleles for starch and water-soluble polysaccharides. Hybrids containing the *su1-pu* allele accumulated the greatest amount of starch and the lowest amount of water soluble polysaccharides (WSP), and those with the *su1-ne* allele had the lowest amount of starch and greatest WSP. De Vries and Tracy [28] determined that a mutant of the *isoamylase2* (*isa2-339*) gene significantly modifies carbohydrate composition in *su1-ref* inbreds as well as flavor characteristics of *su1* sweet corn. Kernels with two doses of the su1-ref allele have more WSP and less starch than kernels with a single dose of the su1-ref allele. Starch content is further reduced in *su1-ref, isa2-339* double mutant genotypes compared to the *su1-ref* parent. The *su1-ref/su1-ref, isa2-339/isa2-339* lines developed in this experiment are the first documented double mutants of su1-ref with another isoamylase starch debranching enzyme mutant. Trimble et al. [29] evaluated the five naturally occurring mutant alleles identified at the *su1* locus. The inbreds with those alleles were backcrossed to A619 and A632, two modern field maize inbreds for evaluating seedling emergence, field traits, and mature kernel composition. The authors found significant differences among the su1 alleles, where *su1-ne* was consistently inferior for emergence and field traits while the *su1-pu* allele was consistently better than the other *su1* mutant alleles for the evaluated traits. Differences were observed in the presence of ISA1 enzyme; however, no functional ISA1 enzyme activity was observed.

Other mutants used in sweet corn have diverse viability problems. Xavier et al. [30] studied the potential of supersweet corn inbreds based on *brittle2* (*bt2*) for commercial varieties. General combining ability and specific combining ability were significant, and there were some hybrids with superior performance that could be included in a breeding program for increasing grain productivity, large ear diameters, and long ears. Jha et al. [31] investigated allelic relationship using complementation of mutant alleles in 16 sweet corn genotypes and two testers and found that normal kernels appeared due to complementation of dissimilar mutants, whereas no complementation of similar alleles leads to sweet corn kernels. They hypothesized that kernel phenotype-based genetic complementation is a simple tool and can be used efficiently in grouping of endosperm mutants.

The mutant sugary enhancer1 (se1) occurs naturally and alters starch metabolism in the *su1* maize endosperm [32]. It is a recessive modifier of *su1* and commercially important in modern sweet corn breeding. Homozygous *se1* in a homozygous *su1* background has less starch and more WSP and sugars than *Se1Se1/su1su1* and wild type [32]. *Se1* is on chromosome 2 and an absence variant causes the se1 phenotype. *Se1* is predominantly expressed in the endosperm with low expression in leaf and root tissues.

High sugar types, *sh2* and *bt2* have the most severe negative effects which, initially, were a hindrance to the acceptance of the high sugar types. Breeding and improvements in seed production techniques and seed treatments have greatly reduced these problems [1,2]. Performance is affected by genetic background, seed production environment, production methods, chemical seed treatments, and seeding environment [1,2]. In many backgrounds *su1* performs similarly to *Su1*.

2.4. Other Mutations

Another consideration with recessive mutants is that outcrossing can negatively affect table quality. Outcrossing can be prevented using gametophyte factors, such as *Ga1-s*, which protect maize silks from foreign pollen. Revilla et al. [33] introduced the gametophyte factor *Ga1-s* in *sh2* inbred lines for protecting sweet corn against contamination with *Sh2* pollen. The gametophyte factor *Ga1-s* effectively protects the *sh2* plants and yields a stable effect across environments because of the gene x genotype interactions so donors of *Ga1-s* that favor the viability of *sh2* must be chosen. Some *su1* lines have the universal pollinator allele and may overcome *Ga1-s* [34].

The glume is an organ that protects the maize spikelet during anther and kernel development. The glumes surrounding the kernel reduce how deeply one can bite or cut kernels off the cob. Eliminating glumes could be a way to increase yield of cut kernels. *Vestigial glume1* (*Vg1*) is a semi dominant mutant that eliminates the glume in the male and female spikelets. Complete elimination of the glume in the male spikelet results in male sterility. Liu et al. [35] reported the phenotypic characterization, fine mapping, and candidate gene analysis of the *Vg1* mutant. *Vg1* is semi-dominant and has pleiotropic effects over plant height, ear height, and tassel length. That information can be useful for maize breeding of small-glume varieties, especially sweet corn.

2.5. Breeding Programs

The availability of superior and diverse sweet corn inbred parents, particularly of the *sh2* allele, is one of the major bottlenecks to developing high yielding, high quality sweet corn hybrids. For that reason, several attempts have made to convert field corn into sweet corn through backcrossing. Though the success of those methods has been limited, there are reports of breeders using this method. Jha et al. [36] used a modified backcross breeding method coupled with phenotypic comparison with a recurrent parent, followed by backcrossing three times and self-pollination. The authors report that the modified backcross method used is rapid, cost effective and can be used by maize breeders with limited resources for conversion as well for diversification of sweet corn germplasm.

The bottleneck is reversed in *su1*, where variability is relatively large, and the demand limited. Chhabra et al. [37] developed a su1 based functional marker by using six diverse inbred lines of sweet corn and five wild type inbred lines with 27 overlapping primers and reported that the markers (SuDel36-FR and SNP2703-CG-85/89) can be used in marker-assisted breeding program.

Pericarp, the outer most layer of the sweet corn kernel, directly affects kernel tenderness, an important determinant of quality and consumer preference. Thin pericarp is associated with greater tenderness. Wanlayaporn et al. [38] used pericarp weight as a proxy for pericarp thickness to identify quantitative trait loci controlling pericarp thickness in 109 recombinant inbred lines of sweet corn from Thailand. They found a major QTL that explained 73% (immature stage) and 41% (mature stage) of the phenotypic variance and concluded that the QTL could be useful for marker assisted selection (MAS) for tenderness. Wu et al. [39] used genetic mapping combined with transcriptome analysis to identify candidate genes controlling pericarp thickness. They identified novel quantitative trait loci for pericarp thickness in a sweet corn BC4F3 population of 148 lines and constructed a high-density genetic linkage map containing 3876 specific length amplified fragment (SLAF) tags for mapping QTLs for pericarp thickness. They identified 14 QTLs for pericarp thickness and proposed forty-two candidate genes, five of which were differentially expressed between the two parents.

Sa et al. [40] assessed the genetic and phenotypic variation of six agronomic traits using 90 supersweet inbred lines and performed association analyses using 100 simple sequence repeats. They identified four marker-trait associations involving three markers that were associated with days to tasseling and days to silking, and four significant marker–trait associations. The detection of loci associated with such traits can be used in marker-assisted selection and assist breeders in choosing parental lines for crossing combinations, and markers for using MAS in supersweet corn breeding programs in Korea. Cheng et al. [41] identified 15 and 14 additive QTLs quantitative trait loci by unconditional and conditional mapping, respectively, in a recombinant inbred line population derived from a BF3109 x Q267 cross for use of endosperm carbohydrate reserves during germination in supersweet corn. Identification of QTLs based on a combination of time-dependent measurements is important for a better understanding of the genetic basis of use of seed reserves.

Doubled haploid (DH) technology is an important part of most field maize breeding programs. DH lines are produced by using various haploid inducer lines [42]. The haploid inducer R1-navajo (R1-nj) gene produces diploid kernels with colored aleurone crowns and scutella and haploid kernels with colorless scutella. However, R1-nj gene expression depends on genetic and environmental factors that can mask the typical R1-nj phenotype. In order to solve this problem, Yu and Birchler [43] introduced a dominant green fluorescent protein (GFP) marker gene into a maize haploid inducer to generate the RWS-GFP inducer that allows the identification of haploids by visualizing the GFP expression of germinated kernels because diploid seeds produce GFP fluorescence in radicles and coleoptiles, while haploids lack the paternal GFP gene during hybridization with the haploid inducer.

Mutants are combined for improving quality; for example, incorporation of sweetness into waxy background is a means to improving waxy corn taste. Simla et al. [44] attempted incorporation of sweetness into waxy backgrounds by determining the best gene combination. The genes *su1*, *sh2*, and *brittle1* (*bt1*) were incorporated into waxy background. Waxy endosperm was negatively associated with sweetness and crispness, whereas sweetness was positively associated with crispness and overall liking, indicating that increased sweetness in waxy corn can increase consumer preference. When combining several mutants, maternal effects should be considered. Dermail et al. [45] studied the importance of reciprocal effects, potential heterosis, and their relationship, emphasizing agronomic traits, yields, and yield components of sweet-waxy corn hybrids in Thailand. Reciprocal cross effects significantly impact heterosis, which has important implications for breeding programs. Altinel et al. [46] evaluated sweet and field corn hybrids and their parents for kernel color, size, and quality properties and found that kernel size and weight of hybrids were similar to those of the male parents, but male parents had higher color parameters than the hybrids, and sugar content was similar in parents and hybrids. The authors concluded that it is possible to produce new sweet corn x dent corn hybrids with improved characteristics.

3. Stresses

Poor emergence and seedling vigor associated with altered starch synthesis alleles in sweet corn are exacerbated in the presence of unfavorable environmental conditions and are among the main factors restricting the spread of sweet corn as crop. Consequently, several researchers focus on early vigor, but the assessment is complicated. Qiu et al. [47] tested a rapid method for distinguishing viable and nonviable supersweet corn kernels, based on single-kernel Fourier transformed near-infrared spectroscopy (FT-NIR) with 1000–2500 nm wavelength range. They concluded that the FT-NIR technique with multivariate data analysis methods showed promise in rapidly and non-destructively detecting seed viability in supersweet corn.

Cold and wet soils have severe effects on sweet corn emergence and seedling vigor. Sweet corn breeders frequently use field corn genotypes for broadening the narrow genetic base of sweet corn, providing favorable alleles for stress tolerance, but they have to deal with the reduced viability of defective endosperm alleles plants within some field corn genetic backgrounds [48]. The authors detected different numbers of QTLs in diverse genotypes and environments while finding the viability of the sweet corn allele is under genetic and environmental control with significant additive effects due to multiple genes with minor contributions. There are specific genes involved in mutant viability that depend not only on the specific mutant and the environment but also on the genetic background into which the mutant is introduced. Some of the QTLs identified in this study explained large proportions of variance and could be used by sweet corn breeders in breeding new genotypes from field x sweet corn crosses. Similarly, Wu et al. [49] studied the molecular mechanisms and genetic basis for early seed vigor and identified 18 QTLs, including a stable QTL with four candidate genes potentially related to seed vigor after artificial aging. Cheng et al. [50] studied the physiological process of seed reserve utilization in supersweet corn during germination and found genotypic differences in efficiency. Protein content and number were highest in the early stage of germination while enzyme activity was highest in the germinating seed and differed among genotypes and germination stages. They concluded that improving seed reserve utilization in sweet corn could be accomplished by identifying the physiological mechanism of germinating seed.

Huang et al. [51] studied the metabolism and interaction of plant growth regulators and applications of spermidine as an enhancer of seed vigor concluding that the hormonal modifications caused were promoted by direct effects on plant growth regulators. The overall quality of seeds depends on their treatment. Somrat et al. [52] compared the efficiency of three binders on the physical and antioxidant properties of pelleted sweet corn seeds. The three binders had better pelleting integrity, germination index, seedling growth, and shoot growth rates than non-ionic polyacrylamide and non-pelleted seeds. Suo et al. [53] evaluated the potential effectiveness of plant growth regulators in improving germination and seedling vigor when applied during seed coating. They added 6-benzylaminopurine (6-BA), 1-naphthalene acetic acid (NAA), brassinolide, and gibberellic acid (GA(3)) to seed coating agents and found that plant growth regulators improved seed vigor, germination and antioxidant capacity that resulted in visually superior sweet corn seedlings. They concluded that plant growth regulators might be valuable agents in sweet corn seed coating.

3.1. Drought

The most important abiotic stress for agriculture, and for sweet corn specifically, is drought. There is variability for drought tolerance in maize but, unlike USA dent corn, temperate sweet has not been bred by drought tolerance. An example of the problem is provided by Hirich et al. [54], who acknowledge that climate change is a major concern for humanity. As climate projections for temperate regions indicate that temperature will increase, and precipitation will decrease over a few decades subsequently impacting water availability negatively. Using the SALTMED model for sweet corn in the Maroquian region, Hirich et al. [54] found that the growing season for maize would be shortened by 20 days due to increasing temperature decreasing water requirements 13%. However, crop evapotranspiration is projected to increase by 15% resulting in an overall yield reduction of 2.5% by the century's end.

Drought causes osmotic stress that reduces water absorption and seed moisture contents, seed germination, vigor index, seedling growth and fresh and dry biomass [55]. These authors found that osmotic stress triggered antioxidant defense systems and accumulation of soluble sugars, proline, and protein contents. Overall, germination potential decreased with increased osmotic stress in sweet corn seeds. Nemeskeri and Helyes [56] reviewed the response of green peas, snap beans, tomatoes, and sweet corn to water stress based on their stomatal behavior, canopy temperature, chlorophyll fluorescence and chlorophyll content of leaves, which are stress markers that can be used for screening drought tolerance of genotypes, setting irrigation schedules or prediction of yield. Nemeskeri et al. [57] studied the spectral reflectance at leaf and canopy levels, leaf area index during development, and their relationship with yield and nutritional quality. Drought reduced plant height, diameter and weight of ears per plants, total carotenoid content of kernels, Soil Plant Analysis Development (SPAD) of leaves, and leaf area and yield, and these effects depended on the genotype and the developmental stage at which they were measured.

As genetic diversity for drought tolerance is limited in sweet corn, some authors confront drought stress by using agronomic strategies, such as optimizing irrigation management when available. Nocco et al. [58] created high resolution evapotranspiration maps to assess water stress and apparent soil electrical conductivity in the Midwest United States. They used the maps and compared them with ground observations in potato, sweet corn, and pea agroecosystems and found that their models have stronger relationships in sweet corn and potato rotations than field corn. Thus, they recommend determining potential water use, savings, and yield gains from precision irrigation. Nocco et al. [59] proposed a precision irrigation system for optimizing water use efficiency under variable climatic conditions. They concluded that regional water management strategies could be effective in buffering against the interannual climate variability of recharge, while localized management strategies could increase irrigation efficiency by targeting crop and soil texture drivers. Water deficits reduce leaf area but can be compensated with irrigation [60]. These authors found that plants counteract leaf stress by activating a mechanism of photosynthetic compensation. Irrigation must be optimized, particularly when water availability is limited in order to minimize drought stress. Sweeney et al. [61] investigated the timing of irrigation and fertilization and found that early planting results in better water use efficiency but increases the risk of cold and flooding stress. They found that fertilization regimes had negligible effects.

Unfortunately, irrigation may lead to secondary consequences on production and quality. Kara et al. [62] demonstrated that irrigation affected mineral nutrient content of fresh sweet corn kernels. The highest content of nitrogen, phosphorus, potassium, calcium, magnesium, iron, copper, and manganese were obtained at moderate water deficits, while the highest zinc amount and the highest boron amount were produced at the highest and the lowest irrigation levels, respectively. Peykarestan et al. [63] recommended the application of zinc sulfate in the form of ZINC FAST with irrigating alternate furrows thus decreasing water consumption and the enrichment of zinc content of sweet corn. Santos et al. [64] evaluated the influence of irrigation on sweet corn production and found a positive influence on the recovery of damage caused by defoliation at the initial developmental stages. Furthermore, they found that successful irrigation management as a strategy to mitigate damages caused by defoliation depends on the level of leaf area lost and the amount of water used [64].

Water and nitrogen efficiency play key roles in plant drought tolerance. During kernel-filling, increasing photosynthetic nitrogen use efficiency can increase whole-plant N-utilization efficiency. Jafarikouhini et al. [65] found that improving photosynthetic nitrogen use efficiency within the canopy, or improving whole-plant nutrient use efficiency under water stress without nitrogen, contribute to physiological acclimation of sweet corn to drought.

When appropriate irrigation is not available, crop production depends on climatic conditions. Climate change causes irregularity of rainfall, affecting the availability of groundwater, and decreases crop production. Sumani et al. [66] investigated environmental conditions for sweet corn production and found that some soils could be improved for sweet corn production by adding organic matter. Alternatively, some crop treatments can minimize the effects of drought stress. For instance, Habibpor et al. [67] evaluated the effect of salicylic acid on yield and some morphological and physiological characteristics of sweet corn under water stress. The authors found that the effect of water deficit stress was significant on all the traits studied and application of salicylic acid reduced the resulting negative effects.

Though drought is the main water stress, sweet corn seeds are sensitive to flooding. However, it is not clear if there is genetic diversity for tolerance to flooding, as multivariate evaluation of the physiological potential of seeds was not efficient for assessing early vigor to verify if the submersion test has potential for classifying seed lots [68].

3.2. Temperature: Cold and Heat

Another consequence of the presence of endosperm mutants and the genetic background of Northern Flint is that that sweet corn can be particularly susceptible to extreme temperatures at seeding. Temperature stress, either low or high, affects sweet corn altering diverse aspects of plant development, including vitamin E and carotenoid content in seedlings [69]. Vitamin E accumulation was limited by high temperature while carotenoid production was suppressed by low temperature and promoted by high. They proposed an interactive and competitive relationship of vitamin E and carotenoids in sweet corn seedlings as response to extreme temperature stress at transcriptional and metabolic levels. Cold temperature represents a widespread environmental stress that strongly affects maize growth and yield. Mao et al. [70] investigated the transcriptome profiles of sweet corn under cold stress and suggested that transcription factors may play a dominating role in cold tolerance of sweet corn. They proposed a set of candidate genes associated with response to cold temperature in maize.

As improving cold tolerance of sweet corn is not an easy task, one of the possible solutions is protecting seed from cold stress by artificial treatments. Gao et al. [71] developed a thermo-responsive coating material with dual efficacies of intelligent chilling-resistance and anti-counterfeiting for maize seed. The coating material was made of salicylic acid and rhodamine B co-loaded poly (N-isopropylacrylamide-co-butylmethacrylate) hydrogel. Compared with the basic coating agent, the proposed significantly enhanced seed germination percentage by 17.8% and vigor index by 53.1% under chilling stress and improved seedling shoot height, dry weight, and maximal quantum yield of PSII (Fv/Fm). Douds et al. [72] suggested the use of arbuscular mycorrhizal fungi for improving phosphorus uptake and establishment under low soil temperature. They proposed pre-incubation in the greenhouse of arbuscular mycorrhizal fungi in compartmented flats of potting media for enhancing formation of mycorrhiza.

3.3. Salinity

More than 50% of agricultural and irrigated lands are affected by salinity. Salt stress limits the availability of nutrients in the soil, induces physiological disorders, and antioxidant dysfunction in plants; hence, it influences plant growth and productivity. Kale et al. [73] determined the effects of salinity and fertilizer dosage on yield under greenhouse condition. Salinity reduced dry and wet plant weight. Tekeli et al. [74] reported that salinity increased carbon isotope ratio of leaves and, subsequently, reduced yield under high salinity.

As genetic improvement of salt tolerance is not viable, several authors have found alternative solutions. Adibah et al. [75] determined the effects of betaine-rich nano fertilizer on growth parameters of sweet corn under salt stress. Betaine-rich nano fertilizer significantly increased plant height, number of leaves, root length, leaf length, and root:leaf length ratio in sweet corn. They also found that, under saline conditions, the nano fertilizer improved plant growth and development through reducing damage by salt stress. Huang et al. [76] demonstrated that biochar application enhanced growth of sweet corn and controlled salinity; therefore, they recommended the use of biochar for growing sweet corn in coastal areas with salt stress. De Oliveira et al. [77] assessed the use of biostimulants for promoting growth and increased crop yields under salt stress in popcorn and sweet corn and found that seed treatment with biostimulants promotes development but did not inhibit or lessen the effect of salinity on the plants.

3.4. Other Abiotic Stresses: Plant Density, Water Aeration, and General Adaptation

Density stress tolerance is the extent to which the crop maintains yield per unit area as plant population density increases beyond standard levels. Sweet corn hybrids grown for processing vary widely in tolerance to crowding stress. Williams [78,79] and Dhaliwal et al. [80] studied the extent to which sweet corn is affected by crowding stress tolerance and the economic and agronomic implications of increasing plant density. The combination of traits loading into the source–sink relationship factor was positively related to ear mass, case production, and gross profit margin [81]. Dhaliwal et al. [82] evaluated different models to understand variability in optimum plant density and identifying crowding stress tolerant processing sweet corn.

Oxygen availability in water affects sweet corn development. Lei et al. [83] compared diverse types of aeration and found that corn biomass was significantly greater for the Venturi treatment compared to both the fluidic oscillator and control treatments. Pan et al. [84] suggested that soaking seed with exogenous gibberellic acid was a simple and practical method to improve deep-sowing tolerance during germination, and significant improvement was attributed to vigorous respiratory metabolism. Metabolism time and critical oxygen pressure increased and relative germination time decreased while oxygen metabolism rate and relative germination rate increased in gibberellic acid-soaked seeds, suggesting that exogenous gibberellic acid accelerated seed respiration.

Saito et al. [85] compared the root apical meristem organization between teosinte and sweet corn for understanding how the evolutionary processes and the domestication of maize have affected root development. Metaxylem development in teosinte differed from sweet corn in the numbers of late-maturing metaxylem vessels and promeristems of both were identical. Mitotic activity was rare in the quiescent centers. This study could allow a better understanding of response to domestication and, therefore, selection for adaptation.

4. Insects

4.1. Insects Pests

4.1.1. Corn Borers

The European corn borer (ECB), *Ostrinia nubilalis* (Hubner), was introduced in North America in the early 1900s where it became a major pest of corn. Early life history studies indicated that ECB has a wide host range. Today, ECB is a major insect pest of sweet corn around the world. ECB results in substantial yield decreases and lost profits for farmers. Pressure from ECB is affected by environmental factors, such as water availability. Ucak [86] demonstrated that irrigation increases populations of both ECB and Mediterranean corn borer (MCB) (*Sesamia nonagrioides* Lefebvre) in sweet corn while drought reduces their populations. Investigating pest tolerance normally requires artificial inoculation of the pest species, which is not always available. The Asian corn borer ACB (*Ostrinia furnacalis*, Guenee) is an important pest that is poorly studied. Rahayu et al. [87] tried to develop a rearing method for investigating ACB and identified some diets that were appropriate for rearing ACB.

4.1.2. Corn Earworm and Fall Armyworm

Corn earworm (*Helicoverpa zea* Boddie) and fall armyworm (*Spodoptera frugiperda* J. E. Smith) are important pests in sweet corn. The corn earworm lays eggs in the silk, but also can use maize tassels as egg-laying sites at tassel emergence stage, as well as leaves. Rhino et al. [88] concluded that tassel emergence stage is the best period for controlling *H. zea* in maize fields and the best phenological stage to use maize as a trap crop for the pest. Olmstead et al. [89] reviewed the pest status of *H. zea* and its life history and abiotic factors that affect it. They described monitoring methods, crop protection management decisions, chemical control options, and the use of genetic technologies for control of *H. zea*. Alternative pest management including biological control, cultural controls, host plant resistance, and pheromone disruption are also reviewed.

4.1.3. Pictured Wing Flies

Eleven species of these Diptera (Ulidiidae) attack maize in America. Goyal et al. [90] reported that developmental times are significantly affected by species and season. *Euxesta* *stigmatias* Loew, *Euxesta eluta* Loew, and *Chaetopsis massyla* Walker attack sweet corn and render ears unmarketable. These fly species can have more than 15 generations per year in southern Florida. *E. eluta* adults live two to three times longer than other species, and females of all species live longer than males. Owens et al. [91] studied the preferences of oviposition substrate and found that frass from the fall armyworm, *S. frugiperda,* is more attractive than other ovipositional substrates for *E. eluta* and *C. massyla* and tassels are more attractive than leaves while only *C. massyla* prefer silks to tassels. Owens et al. [92] used baited monitoring universal moth traps for studying the dynamics of cornsilk flies and demonstrated that all species could be captured in traps currently used for pest monitoring with Torula yeast as a leading attractant. Owens et al. [93] determined that crop destruction is not a reliable reduction method in 1st generation adult picture-winged flies' emergence from ears at post-harvest.

4.1.4. Silk Fly

Corn-silk fly (*Euxesta* sp.) is a highly polyphagous insect genus that affects horticultural crops, fruit trees, and industrial crops. It causes serious economic losses in sweet corn. Damage is caused by larvae feeding on corn silks, kernels, and the cob. Chemical treatments applied to maize crops can be effective, but require numerous applications; therefore, efforts to control the fly focus on finding alternative methods, such as biological control. *Euxesta* species has been studied by Lopes et al. [94]. They evaluated the efficiency of food attractants placed inside McPhail traps to remove adult insects to reduce ear damage and they captured the most insects between silk emergence and kernel filling with more females than males. Ear damage was low; therefore, the use of McPhail trap containing food attractants may be a viable alternative to control corn silk flies in small areas.

4.1.5. Long-Legged Flies

Long-legged flies (Dolichopodidae) are classified in 11 genera with 33 species and can be found in sweet corn. Kautz et al. [95] highlight the potential that highly attractive but intensively managed croplands may act as ecological traps, with consequences for Dolichopodidae conservation.

4.1.6. Stink Bugs

The southern green stink bug (*Nezara viridula*) has recently become a pest of primary concern. It is a polyphagous pest of many crops during both the nymph and adult stages. Canton and Bonning [96] performed biochemical and transcriptomic analyses to characterize digestive enzymes in the salivary glands and along midgut tissues of *N. viridula* nymphs and adults that fed on sweet corn and found that different regions of the digestive tract of *N. viridula* have specific and distinct digestive properties increasing our understanding of the physiology of this organism.

The invasive brown marmorated stink bug (*H. halys*) is a major pest of agricultural crops east of the Mississippi River. *H. halys* is an invasive and economically damaging insect pest in U.S. agriculture that feeds on more than 300 plant species, including sweet corn. Zobel et al. [97] reported the seasonal abundance, host preference, and injury potential of *H. halys* on sweet corn and other vegetables. *H. halys* prefers host plants with reproductive structures for feeding and was more abundant on vegetable crops that had extended periods of fruiting like sweet corn. Cannibalism occurs in these predatory and phytophagous insects, but only two phytophagous pentatomids are cannibalistic. Iverson et al. [98] identified cannibalism on the hatch rate of eggs.

4.1.7. Northern Corn Rootworm

A key maize pest, northern corn rootworm (*Diabrotica barberi*), is a univoltine species occurring in mid-western and eastern North America; maize is the preferred larval host [99]. The eggs are laid in the soil of maize fields, where they overwinter and can diapause for more than one winter. Larvae hatch between spring and summer and adults emerge at midsummer to feed on maize tassels, silks, and ear tips. After adults abandon maize, they look for other feeding hosts and return to maize for oviposition between summer and autumn.

4.1.8. Mexican Corn Rootworm

The Mexican corn rootworm (*Diabrotica virgifera zeae*) (Coleoptera: Chrysomelidae) is one of two subspecies of *D. virgifera* of Central America and southern North America [100]. Larvae prefer to feed on maize roots while adults feed on the leaves, silks, pollen, and immature seeds of maize. Eggs are laid in the soil of maize fields between summer and autumn, hatch in late spring and adults live in maize fields from late spring to winter. *D. virgifera zeae* is univoltine but can have multiple overlapping generations each year. *D. virgifera zeae* and *Diabrotica virgifera virgifera*, western corn rootworm, are prominent maize pests in the USA.

4.2. Insect Management

4.2.1. Plant Breeding

Plant breeding for increased insect resistance is very limited in sweet corn. Demirel and Konuskan [101] reported genetic variability for ECB damage on stalk and corncobs of various sweet corn varieties in Turkey and found that damage was variable for different plant parts and in different environments. Rhino et al. [102] found significant genetic diversity among sweet corn genotypes for attractiveness to oviposition and resistance to *H. zea*. Moore and Tracy [103] assessed the feasibility of reducing corn earworm damage by selecting sweet corn with longer husks without shortening the ears. Selection was successful but did not reduce corn earworm damage. They later examined the interaction between husk length and maysin concentration in silks [104]. Effects of husk extension and maysin on corn earworm resistance were inconsistent, but five inbreds produced hybrids with significantly lower corn earworm infestation and/or damage, demonstrating potential to confer resistance to the corn earworm [104].

4.2.2. Transgenic Maize

Transgenic maize with genes from the bacterium *Bacillus thuringiensis* (Bt) reduce pests and insecticide usage, promote biocontrol services, and economically benefit growers. Area-wide Bt adoption suppresses pests regionally, including on neighboring non-Bt crops. Transgenic maize is available for field corn production throughout most of the World. Production of transgenic corn is not allowed in several countries, while, in other countries, the presence of transgenic maize in food products requires specific labelling. Transgenic sweet corn is also available for production in some countries. In the US, transgenic sweet corn is not used for commercial processing, but can be used for fresh market production and is estimated at less than 20% of total production acreage.

Dively et al. [105] demonstrated that growers in the Mid-Atlantic United States benefit from Bt corn via decreased crop damage and insecticide applications. Widespread use of Bt corn suppressed ECB and corn earworm and decreased economic levels for injury in vegetable crops with reduced adult populations. These authors showed decreases in the number and amount of required insecticidal application. However, Schmidt-Jeffris et al. [106] determined that in their study area ECB does not respond to local levels of Bt corn in the landscape and numbers of ECB captured in pheromone traps placed by snap bean fields and proximal sweet corn fields were not related. Thus, this indicates that snap bean growers should not make control decisions based on adult activity in sweet corn. Dively et al. [107] reported that widespread use of transgenic corn with genes expressing toxins from *B. thuringiensis* and the evolution of insect resistance is a major threat to the sustainability of Bt transgenic technology. They also found that the high dose requirement of Bt corn expressing Cry toxins for resistance management is not achieved for corn earworm because this pest is more tolerant of Bt toxins.

Fisher et al. [108] found that the growth and survivorship of ECB was higher in non-Bt corn and Bt was effective in killing ECB larvae. Schneider et al. [109] evaluated the efficacy of Bt sweet corn, alone and in conjunction with insecticides, against major lepidopteran pests found in Midwestern Brazil, specifically *S. frugiperda*, *H. zea*, and *H. armigera*. Bt sweet corn reduced the rate of defoliation caused by *S. frugiperda* and resulted in fewer larvae of *S. frugiperda* and *Helicoverpa* spp with less severe injury on corn ears. Insecticides did not improve the protection of Bt sweet corn and there were no significant differences in ear size and weight or kernel yield as a result of insecticidal treatments.

Increasing temperatures affect insect life histories and their management. Venugopal and Dively [110] reported that sweet corn damage by corn earworm decreased with Bt adoption but that increasing temperature, accelerates the development of Bt-resistant insects thus decreasing the efficiency of Bt corn. They concluded that climate change has to be included in models of transgenic maize pest control. Kahn and Brandenberger [111] developed protocols for fall sweet corn production, examining a transgenic cultivar that expresses the CryIA(b) toxin from B. thuringiensis and its non-transgenic near-isoline under various seeding rates, planting dates, and insecticide regimes. Genetic resistance to lepidopteran pests was a critical factor for successful production of fall sweet corn. Bt sweet corn increased production of premium ears by reducing the percentage of ears with severe insect damage. A spray schedule that rotated two insecticides with intermediate mammalian toxicity (carbaryl and permethrin) was effective in reducing severe insect damage to ears of the transgenic variety.

4.2.3. Natural Enemies

Natural enemies are one of the most sustainable methods for controlling pests. The use of *Trichogramma* wasps is an effective biological control of ECB in sweet corn, but manual applications are inefficient. Gagnon et al. [112] investigated the use of *Trichogramma* spp. for ECB management as potential biological control agent for large areas in processing sweet corn. Their objective was to evaluate economically and environmentally sustainable alternatives to insecticides for controlling ECB populations. They found that low doses of *T. ostriniae* released a few times over large crop areas significantly decrease ECB presence and ear damage. *Trichogramma* is an economically competitive alternative to insecticide applications. Dionne et al. [113] developed a mechanized introduction of *Trichogramma* using a boom sprayer saving time and labor. The applications resulted in high parasitism rates and adequate control of ECB. Gauthier et al. [114] demonstrated the technical feasibility of spraying *Trichogramma* pupae to facilitate spread and reduce operating costs for controlling ECB in corn crops, suggesting this method could be generalized to other predator insects.

Viteri et al. [115] found that larvae of corn earworm and fall armyworm were susceptible to *Steinernema carpocapsae*. One of the most ubiquitous predators of corn earworm and other lepidopterans is the insidious flower bug (*Orius insidiosus*). Peterson et al. [116] observed that *O. insidiosus* is effective at controlling corn earworm in sweet corn and proposed the use of this predator as a control.

Gallardo et al. [117] identified a new genus (*Euxestophaga gallardo*) of Eucoilinae (Hymenoptera, Cynipoidea, Figitidae) and *Euxestophaga argentinensis* Gallardo, sp. n. in Argentina that are parasitoids of *Euxesta eluta* Loew (Diptera: Otitidae) pupae, a pest that attacks Bt sweet corn. Bertolaccini et al. [118] investigated the effects of *E. argentinensis* parasitism on corn-silk fly larvae (*Euxesta* sp) and found parasitism was higher in late winter than late summer, but only *E. eluta* was parasitized. Meagher et al. [119] identified common parasitoids emerging from larvae that are present in sweet corn habitats where insecticides are traditionally used. They found that parasitism was comparable between fall and spring seasons but was much higher in fields without insecticide treatments. The most common parasitoids emerged from larvae were *Cotesia marginiventris*, *Chelonus insularis*, *Aleiodes laphygmae*, *Euplectrus platyhypenae*, *Meteorus* spp., *Ophion flavidus*, and *Tachinidae* sp.

Aphid pests can be controlled with generalist entomopathogenic fungi, such as *Metarhizium brunneum*, specialist predators such as the gall midge *Aphidoletes aphidimyza*.

De Azevedo et al. [120] demonstrated that *A. aphidimyza* applied alone suppressed the aphid population more effectively than *M. brunneum* alone while suppression was greatest when both agents were combined.

4.2.4. Insecticides

While conventional management using multiple applications of insecticides is common practice for processing and fresh market sweet corn, relatively little has been published on the use of insecticides specifically on sweet corn over the last five years. Owens et al. [121] investigated insecticide efficacy of current commercial products for either silk fly or fall armyworm control. *E. eluta* is susceptible to all insecticides tested. *C. massyla* and *E. stigmatias* are resistant to several pyrethroids.

There have been a few articles on the hazards of insecticides. Yajima et al. [122] reported that pesticide residue levels are present in various parts of sweet corn ears, mainly in the silk and husk portions, suggesting that the silk portion consumed could affect pesticide residue levels in the edible portion of corn. As more than one insecticide is often applied to crops to protect plants from pests, Wang et al. [123] developed a multi-residue determination method using gas chromatography. They investigated the dissipation dynamics and final residual levels of chlorpyrifos in sweet corn and soil and determined that it is safe to use on sweet corn with a pre-harvest interval of 16–22 days.

Alternative insecticides are relatively common in scientific literature. Westgate et al. [124] reported on several methods of control of Lepidopteran pests of sweet corn, particularly corn earworm, using organic methods. Direct application of corn oil and *B. thuringiensis* to corn silks reduces ear damage. They found no effect of emulsifiers on ear quality with no differences among corn, soy, canola, and safflower oils in corn earworm control or tip development. The carrier–pesticide combinations with the best ear quality overall were Spinosad in carrageenan or corn oil, and Bt in carrageenan. Moore and Tracy [125] surveyed organic sweet corn producers in the U.S. to examine impacts of corn earworm on organic sweet corn production, how producers are currently managing the pest, and opportunities for plant breeding to reduce its overall impact. They confirmed that corn earworm is the most challenging insect pest for organic sweet corn producers and current management options remain limited. The majority of respondents spray approved insecticides (62%). The most prevalent insecticides are Bt-based (17 respondents), followed by spinosad-based insecticides (13 respondents).

4.2.5. Integrated Pest Management

Management of sweet corn insect pests can be challenging for many growers due to the lack of effective transgenic and chemical control options. A pest management approach using a combination of methods, including cultural practices, plant breeding, and natural enemies appears most sustainable. These tools can also be used to minimize the use of synthetic insecticides when they are available. For example, fall armyworm can be managed with Integrated Pest Management or a broad spectrum of insecticides currently used against existing pests [126].

Disi et al. [127] demonstrated that plant growth-promoting rhizobacteria reduce the attractiveness of plants to ovipositing ECB and is important for integrated management of soil health to improve crop resistance to biotic stressors. The cotton bollworm (*H. armigera*) is among the most damaging agricultural insect pests in the world and its life cycle is determined by temperature. Blum et al. [128] presented a continuous age-structured insect population model driven by satellite-derived land surface temperature to derive population dynamics of the bollworm. Model simulations generally followed the larval population development observed in the field when it was initiated the day before the first larvae were detected, providing realistic population dynamics. With this model, Blum et al. [128] provided a basis for future development of real-time Integrated Pest Management support systems.

Nocco et al. [58] proposed a spatiotemporal dominance model for pest control. ECB adult abundance was positively associated with spatiotemporal dominance of sweet corn in the landscape and high proportional agricultural land use but was unrelated to the previous year's crop. Predator beetles were negatively associated with sweet corn spatiotemporal dominance but not with the previous year's crop or percent agricultural land use. Pest populations were more abundant and predators less abundant in areas with high host plant dominance [58]. Females ECB rely on volatile cues to locate and oviposit preferentially on maize plants. Furthermore, oviposition behavior of females is influenced by soil management, as they lay more eggs on maize plants grown on conventional soil rather than on organic soils that harbor rich microbial diversity.

Integrated pest management practices for corn earworm in fresh and processing sweet corn use pheromone trap counts of male moths for management decisions but Olmstead and Shelton [129] proposed incorporating insecticides for a more efficient control. They determined that sweet corn could be protected more effectively if insecticides were applied to target the most attractive silking periods for female earworm oviposition instead of current integrated pest management practices using pheromone trap catches alone. Reduction in pest damage varied within and between years. The guidelines for integrated pest management imply that pests should at first be controlled by non-chemical methods and, if these are ineffective, the use of chemical methods is allowed [129]. Beres et al. [130] assessed the effectiveness of biopesticides containing Spinosad and *B. thuringiensis* var. kurstaki to reduce the population and harmfulness of ECB. All products reduced the number and harmfulness of larvae on cobs with the best effects after two treatments of biopesticides at higher doses. The effectiveness of biopesticides also depended on weather conditions and chemical pest control was found most effective.

5. Diseases

A large and diverse set of diseases affect sweet corn. Most of the diseases investigated in the last five years are caused by pathogenic fungi, and the main focus was on understanding and controlling disease. Most chemical treatments protect against infection by fungi; few are curative. Efficiency and secondary effects also must be considered. Fungicides can have detrimental environmental effects, and other treatments have variable performance. Michalek et al. [131] conditioned sweet corn seeds with Ag nanoparticles (nAg) and aqueous solutions of $AgNO_3$ and found that Ag in ionic form significantly reduced the abundance of epiphytic microorganisms and increased the germination rate, but reduced growth and biomass of seedlings; conversely, nAg had no detrimental effects on seedlings, an increased the germination rate of the seeds but had a weaker disinfection effect.

5.1. Seedling Blights

Cold, wet spring soil conditions and pathogenic species of *Fusarium*, *Pythium*, and *Rhizoctonia* can kill seeds, reduce germination, and produce yield losses. Ridout et al. [132] studied the effects of *Fusarium temperatum* in sweet corn. This species is more widespread in America and China than previously thought and causes ear rots and ruptured kernels. Solemslie et al. [133] evaluated prevalence of damping-off and seedling blights in conventional and organic sweet corn fields. They found *Fusarium*, *Pythium*, and *Rhizoctonia*. Other fungi were important local problems. Yu et al. [134] found that *Morchella crassipes* introduced into sweet corn, colonized root elongation and maturation zones forming ectendomycorrhiza-like structures and stimulated the development of roots. *M. crassipes* reduced the incidence of *Fusarium verticillioides* in the kernels of mature ears when inoculated into young ears before *Fusarium* inoculation and prevented *Fusarium* infection in corn ears. *M. crassipes* produced abscisic acid, indole-3-acetic acid, and salicylic acid, improving drought resistance, biomass growth and resistance to *Fusarium*. Ajayi-Oyetunde and Bradley [135] identified *Rhizoctonia* spp. associated with seedling diseases of several crops, including sweet corn.

5.2. Northern Corn Leaf Blight

Northern corn leaf blight (NCLB) caused by *Exserohilum turcicum* is the most frequently occurring foliar disease in sweet corn plants grown under humid environments. Chozin et al. [136] observed that effective control measures for controlling the NCLB can be challenging for organic growers and proposed botanical fungicides for controlling NCLB. Lemongrass + galangal rhizome was the most effective solution in suppressing the growth of *E. turcicum* followed by galangal rhizome, lemongrass + clove leaf, betel leaf+galangal rhizome, and clove leaf+neem leaf. Kutawa et al. [137] assessed NCLB disease in Malaysia. They found variation among isolates in colony growth and color. Pathogenicity in sweet corn was also variable among isolates. Puttarach et al. [138] designed a breeding program of MAS for increasing sweet corn resistance to NCLB. They used polymorphic SSR markers closely linked to the Ht genes for NCLB resistance.

5.3. Downy Mildew

This disease caused by *Peronosclerospora maydis* is one of the most destructive diseases of maize. Characteristic symptoms include chlorotic streaks on the leaves with downy growth on the underside and shortened internodes, which resulted in a stunted and bushy appearance. Lukman et al. [139] collected sweet corn and field corn seed samples from Indonesia and all of them had DNA from *P. maydis*, indicating that contaminated seeds are a potential vector for dispersing the disease.

5.4. High Plains Virus

High plains virus (HPV) is found in small grains and commonly transmitted by the wheat curl mite [140]. Seed transmission has been reported but was considered unimportant due to low percentage of infection. In 2016, symptomatic sweet corn was found in fields in Utah with symptoms ranging from chlorotic leaf streaks to stunting and reduced ear set. About 4% of the seedlings showed symptoms within two weeks of emergence in the field. None of the plants died. Yield loss was estimated at 50% for the field. Virus testing using ELISA showed that the plants were infected with HPV and confirmed with RT-PCR, but no wheat curl mites were found on the plants. The infection pattern in the field was consistent with a seedborne disease. Leftover seed obtained from the grower was tested using ELISA, and 70% of the seed tested positive for HPV then verified with RT-PCR. In greenhouse grow out tests of the contaminated seed, 3% of the seedlings showed chlorotic streaks and stunting after three weeks. The results indicate that seed transmission of HPV can be important and result in yield losses. They concluded that seed testing for HPV should be considered. Additional research is necessary to determine if corn variety or virus strain play a significant role.

6. Mineral Nutrition

Adequate mineral nutrition is required for economically optimal yields of sweet corn, which is determined through various ear and kernel components such as size and number. Nutrients can be provided in several ways and researchers are trying to optimize fertility while minimizing negative environmental effects. Nitrogen is the most important required element both in terms of affecting crop productivity and negative environmental effects. Rapid non-destructive measurements of nitrogen concentration in leaves and leaf mass per area are needed for better management of N. Recent technology, such as hyperspectral reflectance spectroscopy and partial least square regression models, offer models with improved performance. Yuan et al. [141] determined optimum wavelength ranges for % N and leaf mass per area estimates and the development and evaluation spectroscopic models. Narrow band reflectance spectroscopy combined with partial least square regression analysis is a promising method for rapid and non-destructive estimates of N content and leaf mass per area in sweet corn and snap bean.

6.1. Inorganic Fertilizers

Excessive fertilization is common practice in intensive agriculture resulting in serious environmental damage. Prasad and Hochmuth [142] estimated nitrogen losses into the environment in commercial vegetable crop production systems that had adopted best management practices and were under a presumption of compliance with state water quality standards. There are no simple solutions for reducing N losses in crop production, but strategies must focus on managing crop residues, using recommended fertilizer rates, and avoiding late-season application of nitrogen. Optimization of fertilization rates is crucial in making agriculture more sustainable. Zucareli et al. [143] evaluated the effects of side-dressed nitrogen rates at different growth stages in sweet corn seed production and concluded that nitrogen applied at a rate of 120 kg ha-1 at V6 increased seed yield and maintained protein content in sweet corn kernels. They noted a slight decrease in P content and an increase in Zn content of kernels at low nitrogen rates. Kang et al. [144] reported that optimal fertigation was efficient in reducing N and P soil residuals and, combined with a summer catch crop, could temporarily retard N leaching to improve nutrient recycling in the root zone. Xiong et al. [145] reported that the yield of sweet corn was significantly affected by different amounts of fertilizer and different ratios.

Several authors studied optimum fertilization rates and methods for their target area. Khan et al. [146,147] identified the most appropriate combination of density, N levels, and sweet corn varieties for a Pakistani location. Turk and Alagoz [148] studied the optimum rates of nitrogen fertilizer in a Turkish location. Nitrogen applications increased plant height, ear length, ear diameter, single fresh ear weight, fresh ear yield, and crude protein ratio while first ear height was not affected by N rates. Mohammed et al. [149] reported that the quality of several sweet corn varieties was affected by N fertilization levels. Yuan et al. [150] adapted a model to cultivate sweet corn in sand with irrigation and fertilization. Their approach significantly enhanced crop productivity compared to conventional practice, while reducing N fertilizer inputs and NO3-N loading, relative to the highest N input treatments. The adaptive strategy has potential to achieve target crop yields while minimizing NO_3-N leaching. Tang et al. [151] proposed a promising method for improving crop production and environmental conditions by intercropping sweet corn with legumes. Intercropping improved total land equivalent ratio, improved yield and reduced soil mineral input. Marlina et al. [152] determined the dose of organic and inorganic fertilizers for increasing N, P, and K nutrient uptake, growth and yield of sweet corn on an Inceptisol soil. Rates of 75% of inorganic fertilizer + 5 ton/ha organic fertilizer were optimum for N, P, and K nutrient uptake, good growth, and yield of sweet corn.

Cover crops are recommended to mitigate N losses but they can reduce crop productivity. Therefore, optimizing the management-specific cover crop systems may lead to yield improvements. Van Eerd [153] assessed the impact of cover crops, including sweet corn, and planting date on crop yield and N dynamics. Cover crop by planting date interaction affected cover crop biomass and N accumulation, but this interaction did not affect main crop yield or N concentration and accumulation. Furthermore, cover crops improved yield while minimizing potential N losses in the non-growing season, having important implications for sustainable agroecosystems and food security.

One possible solution to nitrogen leaching is using sweet corn as summer catch crop after the winter–spring growing season. Guo et al. [154] assessed the effects of sweet corn as a catch crop on soil N retention and leaching in a greenhouse vegetable system and showed that sweet corn removed some types of residual N in the later growing stage but not in the earlier stages; therefore, other crops should be used as complementary solutions to reduce nitrogen leaching. Strategies to convert high input agriculture to sustainable systems are a priority, and some crop combinations could be more appropriate for sustainable productions under diverse environmental conditions. Shen et al. [155] reported that past nitrogen application rates affected soil electrical conductivity, pH, nitrate–nitrogen, ammonium–nitrogen and carbon source utilization patterns while soil electrical conductivity, nitrate–nitrogen and total phospholipid fatty acids decreased whilst soil organic carbon, pH, and actinobacterial phospholipid fatty acids increased after the establishment of sweet corn as a catch crop. Soil electrical conductivity and ammonium–nitrogen were key factors for carbon source utilization patterns, while pH was the key factor in determining phospholipid fatty acids profiles. Combining a sweet corn catch crop during summer fallow with N at 60% of the conventional rate is a sustainable pathway for using greenhouse-based intensive vegetable soils in eastern China. Zhang et al. [156] evaluated diverse crops to reduce nitrate leaching in the vegetable greenhouse during the summer fallow season. Sweet corn absorbs the residual nitrate in deep soil layers due to its relatively deep root system, but amaranth showed greater N-uptake capacity than sweet corn.

Inorganic fertilization is often applied following general rules without paying attention to specific situations meaning that, often, fertilization is not optimized. Schuller et al. [157] studied the root uptake of radiocaesium by sweet corn and other crops and the potential influence of K-fertilizing on the transfer behavior in umbric Andosol and dystric Fluvisol in a temperate climate with heavy rainfall conditions. The transfer factor decreased exponentially in both soil types but remained within the range of previously reported values for K-fertilized and unfertilized treatments.

Several authors studied the mineral nutrition focusing on the plant. Mondale et al. [158] studied phosphorous concentration and uptake in different plant parts of maize, including in popcorn and sweet corn. Their results showed that P concentration declined with crop growth and there were differences among varieties. The P partitioning at maize harvest was greater in the kernel than in stalk and lower in leaves. Cheah et al. [159] studied the spatial distribution of inorganic nutrients within edible plant parts biofortification. The distribution of inorganic nutrients was largely similar between field and sweet corn but differed among development stages. The micronutrients Zn, Fe, and Mn accumulated primarily in the scutellum of the embryo during early kernel development and secondarily in the aleurone layer at the mature stage. Therefore, the embryo plays a key role as micronutrient reserve for sweet corn.

6.2. Synthetic Organic Fertilizer (Urea)

Due to presence of a carbon atom in the urea molecule, urea is chemically an organic compound. Since it is made synthetically from petroleum, certified organic programs generally reject its use. Liu et al. [160] studied the effects of urea on fresh ear yield and nitrogen use efficiency of sweet corn. Urea improved fresh ear yield and nitrogen use efficiency of sweet corn, with higher root growth, better leaf physiological functions, and increased availability of soil nitrogen. Pangaribuan et al. [161] recommended the integrated use of organic fertilizer and urea fertilizer in sweet corn for decreasing urea use as organic fertilizer gives a better postharvest quality of sweet corn and a better soil health with respect to soil respiration and populations of bacteria and fungi. Rashid and Tanriverdi [162] reported significantly different varietal responses in several agronomic traits and quality parameters to applications of organic N and urea, and diamino phosphate and urea fertilization. They reported Organic N + Half Urea fertilizer application as the best treatment.

6.3. Organic Fertilizers

Organic fertilizers from plants and animals, applied directly or after composting or other processes, can supply significant nutrients to growing sweet corn. Organic fertilizers are mandatory in organic agriculture and often used in conventional agriculture as complementary fertilization or for improving soil properties. A major source of N in organic systems can be from growing N-fixing legumes in rotation with sweet corn. The potential value of animal manure as fertilizer and soil conditioner depends on the rate and speed of organic matter decomposition for releasing plant nutrients or building up the soil organic matter pool. This process depends on manure type and nutrient content, soil temperature, and moisture among other factors. The type of organic fertilizer appropriate for the target area is an important consideration though this objective is rarely the focus of scientific publications. Midranisiah et al. [163] determined that organic fertilizers from chicken manure are the most appropriate type of fertilizer for increasing growth and production of sweet corn crop in a shallow lowland swamp area. From another perspective, soil moisture and organic matter level affect soil respiration and microbial activities, which in turn impact greenhouse gas emissions. Fares et al. [164] evaluated the effects of irrigation levels and organic amendments and found that, among the organic amendments rates, chicken manure mostly resulted in significantly higher soil CO_2 fluxes than bone meal and a control treatment. In addition, organic amendments affect soil moisture dynamics during the crop growing season and organic matter content measured post crop harvest. They recommended the use of bone meal soil amendments to minimize soil CO_2 emissions.

Tannins affect the rate and speed of organic matter decomposition for releasing plant nutrients. Ingold et al. [165] investigated the turnover and nutrient release from tannin containing manure, and found that tannins reduced C, N, P, and K release but the effects depend on the crops. In sweet corn, tannins increased N and P release while C, P, and K were not affected. Lukiwati et al. [166] reported that manure enriched with organic N and P resulted in similar C and Ca production of stover and nutrient concentration of fermented stover compared to inorganic fertilizer. Thus, organic N and P enriched manure could be a viable alternative technology to using low grade phosphate rock, guano, and Gliricidea sepium to produce sweet corn in a Vertisol soil. Emam et al. [167] evaluated the effects of compost and organic extracts on growth and yield of sweet corn and microbial populations in the rhizosphere, comparing extracts of compost, vermicompost, and chicken manure to compost alone and mineral fertilizers. A half dose of compost while adding vermicompost extract had the highest growth, yield, and ear properties of sweet corn, not significantly different from conventional fertilizer. Furthermore, this combination had the highest total bacterial count. Pangaribuan et al. [168] reported that the application of plant compost, enriched paddy straw, and potassium fertilizer applications promoted better growth and higher yield of sweet corn than standard paddy straw compost alone. The application of K fertilizers combined with enriched paddy straw compost showed the best growth and uptake of N, P, and K. Application of compost for sweet corn can be adapted with material in situ such as straw paddy rice. Long et al. [169] compared organic waste amendments with a mineral fertilizer control. Plots amended with biosolids waste co-compost, dehydrated restaurant food waste, and gelatin manufacturing waste produced yields of sweet corn and other crops comparable with the control. None of the wastes evaluated in this study had negative impacts on soil properties, some provided benefits to soil quality, and all produced comparable yields for at least one crop. Their results suggest that all six waste products can be used as sources of plant nutrients.

Poultry litter is abundant in some areas and can be an inexpensive N source in an organic system; however, poultry litter characteristics are variable and nutrient availability for crops depends on several factors. Woodruff et al. [170] determined that poultry litter and a cover crop resulted in sweet corn yields comparable to synthetic fertilizers without accumulation of nutrients or metals. West et al. [171] confirmed the potential for rapid nutrient loss on coarse soil and management challenges due to the asynchrony between organic N release and crop uptake. Weed management affected yield, with early tillage controlling weeds in both green-pea manure and poultry manure treatments. This study demonstrated that in-season organic amendment is beneficial for sweet corn production.

Fahrurrozi et al. [172] showed that liquid organic fertilizer for sweet corn in the soil was almost as effective as foliar application. Xiong et al. [173] reported that yield of sweet corn was not affected by using bio-organic fertilizer or slow controlled release fertilizer. These alternatives allow a reduction of 20% of the fertilization dose without affecting sweet corn yield, though it resulted in reduced nitrogen content in the soil.

Human waste can be processed into fertilizer as part of a sewage treatment process. The process can result in solid fertilizers or liquid (wastewater) types. Gimondo et al. [174] quantified the efficacy of wastewater-grown algae pellets and pastes harvested from rotating algal biofilm systems as fertilizers for sweet corn and other crops. Algae pellets and paste fertilized all the crops, increasing shoot size, dry weight, health, and nutrient concentration. Performance of algal materials was not significantly different from synthetic fertilizer and was better than the commercial bio-based fertilizer.

6.4. Crop Residues

Cover crops can be used as green manure, though this method implies additional costs and environmental impacts. Cover crops are often legumes because they fix atmospheric nitrogen and improve soil properties. Etemadi et al. [175] investigated faba bean as a cover crop and N contribution to subsequent sweet corn under no-till and conventional tillage systems. Number of marketable ears and fresh ear yield of sweet corn were significantly higher in no till than conventional till systems. Sweet corn sown in faba bean residues and amended with an additional 50 kg N ha-1 yielded similarly to sweet corn that received 100 kg N ha-1 with no prior faba bean cover crop. Ivancic et al. [176] measured spring-seeded cover crop biomass, N produced, and subsequent effects on sweet corn yield and response to N fertilizer. Cover crop growth and effects on sweet corn production depended on environmental conditions. Oats did not provide N to the subsequent crop. Fitriatin et al. [177] determined phosphate solubilizing bacteria (*Bacillus mycoides*, *Bacillus macerans*, and *Pseudomonas pseudoalcaligenes*) and cow manure organic fertilizer and green manure significantly increased soil phosphatase, P available, P uptake, and growth of sweet corn. The isolate of *P. pseudoalcaligenes* combined with green manure gave the highest P available in the soil.

Another concern is the interaction between phytosanitary treatments and cover crops. Rojas et al. [178] demonstrated herbicide residue effects on cover crops and potential impact on soil quality parameters. The main interest in using crop residues is for dealing with solid wastes, which is becoming a challenge with an increased demand and production of food and feed, as well as secondary agricultural products, such as palm oil waste. Anyaoha et al. [179] reviewed the option of utilizing palm oil residues as a resource to meet soil and crop demands. Among the alternative uses, pyrolysis, gasification, combustion, and composting are processes that can enhance the value of solid wastes for producing biochar, ash, and compost for soil improvement, soil physico–chemical properties, and performance of sweet corn and other crops, while reducing environmental pollution, increasing income of oil mill processors, and creating savings for farmers.

Soil incorporation of crop residues after harvest is one of the most feasible straw management techniques; however, nitrogen fertilizer should be added to maintain crop yield potential and to maintain N balance in sweet corn. Gao et al. [180] evaluated the effect of soil incorporation of crushed corn ears for sweet corn production and found that straw return combined with an optimized N fertilizer application could improve yield of sweet corn and maintain soil with negligible N loss. Vuyyuru et al. [181] evaluated soil properties related to the decline of sugarcane yield compared to rotation with sweet corn and other crops. Harvest residue incorporated in the soil after harvest increased organic matter, total carbon and C/N ratio and resulted in higher microbial biomass. Rashti et al. [182] observed that application of plant residues resulted in net N mineralization and increased cumulative N_2O emission compared with the application of N fertilizer alone. Mulching of sweet corn decreased total and residue increased cumulative N_2O emission. The application of 3,4-dimethylpyrazole phosphate with sweet corn residue reduced fertilizer, residue, and total induced N_2O emissions. Treatments without 3,4-dimethylpyrazole phosphate application were the most important factor in controlling the magnitude of emissions.

Wheat residues and water management are major problems in wheat–corn rotation, Motazedian et al. [183] incorporated wheat residues into the soil and showed that the greatest plant height and leaf area index were obtained when sweet corn was normally irrigated with partial incorporation of wheat residues. Furthermore, canned yield and water use efficiency increased under normal irrigation and resulted in the highest kernel protein. The highest kernel sugar was achieved with moderate irrigation and partial incorporation of wheat residue. The highest soil nitrogen and organic carbon were reached with normal irrigation and half residue incorporation. Pangaribuan et al. [184] demonstrated that liquid organic fertilizer derived from an extract mixture from lamtoro leaves, banana humps, and coconut fibers increased growth, yield, quality, and nutrient uptake of sweet corn.

Biochar amendments enhance soil quality mitigating greenhouse gases and benefiting microbiological processes. Yu et al. [185] determined that soil type exerted the greatest effect on the soil microbial community, followed by sampling time and cropping system, which exerted a greater effect on the microbial community than biochar treatment. Biochar confers higher-level organization, competition, and complexity to the soil microbiome, which may result in higher resistance to change due to environmental perturbation and, thereby, increase system sustainability. Cole et al. [186] studied sugar maple hardwood charcoal (biochar) as a soil amendment. As soil pH increased with biochar additions, percent base saturation increased due to the retention of calcium, magnesium, and potassium while soil phosphate availability increased. However, sweet corn yield in the biochar-amended soil was depressed if more than 2% application of sugar maple hardwood biochar was applied.

Tropical soils are generally unfertile with low organic matter, plant nutrients, pH and microbial activity. Addition of biochar such as empty fruit bunches could improve soil fertility. Sia et al. [187] found that amending inorganic fertilizers with rice straw compost increased soil pH, total N, available P, exchangeable K, and improved soil nutrient availability, nutrient uptake, and dry matter production of maize. Pangaribuan et al. [188] recommended using enriched rice straw compost for small scale agriculture systems in red acid Ultisol soil because it resulted in better vegetative growth and yield than enriched oil palm empty fruit bunch compost. Suan et al. [189] observed a significant increase in soil pH and available P with oil palm fly ash treatments and a significant increase in exchangeable cations (K, Mg). Therefore, disposal of oil palm fly ash can be used as a liming material to increase soil pH. It also has synergetic effects in combination with inorganic fertilizer. Empty fruit bunch biochar is being used as a soil amendment to improve productivity of infertile soil to enhance plant growth. Abdulrahman et al. [190] showed that combinations of empty fruit bunch biochar without bacteria Sb16 or lower proportions of biochar with bacteria Sb16 inoculation increased populations of soil bacteria, fungi, actinomycetes and N-2-fixing bacteria, enzymes, and soil chemical properties. Empty fruit bunch biochar improved crop growth and soil quality for sustainable corn production.

In addition to crop residues, other sources of residues have been investigated. For example, Possinger and Amador [191] evaluated the use of seaweed for providing nutrients and improve soil quality in coastal agroecosystems. Soil electrical conductivity, K, sulfate, and active carbon increased with seaweed addition, whereas potentially mineralizable N and pH decreased. Sweet corn yield and quality were similar to that produced under equal organic fertilizer. Cole et al. [192] tested the option of using the freshwater macroalga, *Oedogonium intermedium*, to recover dissolved nitrogen and phosphorous from municipal wastewater and using the macroalga as soil ameliorant for producing compost and biochar. That compost increased corn biomass compared to synthetic fertilizer. When biochar was applied in conjunction with compost there was an additional increase in corn productivity.

6.5. Mycorrhiza

In chili pepper–sweet corn intercropping patterns, Hu et al. [193] investigated the potential contribution of arbuscular mycorrhizal fungal hyphal networks and the networks' effects on plant nutrient uptake and interspecific competitive relations. Root mycorrhizal colonization, P acquisition, shoot biomass, and rhizosphere fungal abundance of corn were greater than those of pepper. The authors concluded that constitution of hyphal networks increased mycorrhizal colonization with both crops, and corn supplied part of photosynthetic C for increasing fungal propagules in pepper, and fungi formed better symbioses with corn. Hyphal networks increased pepper fruit yield via improving P distribution to the plants but acquired relatively higher P from corn zone by elevating the soil acid phosphatase activity, suggesting enhanced P competitive ability of pepper against corn through hyphal networks.

Morel fungal species (*Morchella sp.*) form a symbiotic relationship with grasses, increase growth of sweet corn, and suppress Fusarium infections. Phanpadith et al. [194] showed that *M. crassipes* inoculation stimulates maize growth in flint corn. Furthermore, *M. crassipes* affected soil moisture and available K and P accumulation, enhancing growth; the change was not significantly different from plants treated with urea. Inoculation of sweet corn seeds with *Azospirillum brasilense* in association with nitrogen fertilizer may be an agronomic alternative for increasing crop yield and net income of growers. Numoto et al. [195] demonstrated that different rates of inoculation of sweet corn with *Azospirillum brasilense* integrated with nitrogen fertilization management improved phenotypic traits in summer growing periods, under supplemental irrigation. Furthermore, nitrogen fertilizer increased all the traits except kernel total sugars.

7. Weed Control

Weeds compete with crops for nutrients, water and sunlight, and competition is more problematic for weak crops, such as some sweet corn varieties. Weed management strategies differ in their ability to control weeds, costs, and agroecological implications. A recent review of weed management has been published by Simic et al. [196]. These authors analyzed the measures for weed control in maize as part of an integrated weed management system. Sustainable maize production requires reducing chemicals for weed control and replacing them with environmentally friendly alternatives. Crop management systems can be designed to reduce weed pressure such as some rotations of maize with winter cereals and legumes. Mechanical removal of weeds can control some weeds but may increase soil erosion. Placement of fertilizer, plant population density, row spacing, cover cropping, and intercropping can also contribute to weed control. Common vetch as a cover crop has proven ability for controlling weeds in sweet corn.

Given that low seedling vigor is a specific handicap of sweet corn, in some cases limiting the ability of growing seedlings to compete with weeds, some authors have proposed seed treatments for as part of a weed management system. Huang et al. [197] investigated the effect of exogenous Spermidine on seed germination and physiological and biochemical changes during seed imbibition. Spermidine improved seed germination percentage and seed vigor, which was indicated by higher germination index, vigor index, shoot heights and dry weights of shoot and root. They suggested that Spermidine affects metabolism of hormones and supports cell membrane integrity.

7.1. Herbicides

Herbicides are a common resource for weed control, though efficacy and mode of action varies and some have legal limitations due to secondary effects on other crops and non-target species. Some countries forbid or limit some herbicides and inspect imported agricultural products with the objective of removing those with residuals potentially harmful for human health [198–203]. Some herbicides have potential risks for the environment and crops. Choe et al. [204] determined that nicosulfuron, a sulfonylurea herbicide widely used for weed control in corn fields, can damage some sweet corn hybrids and inbreds likely due to the CYP81A9 enzyme responsible for metabolizing nicosulfuron in sweet corn; in addition, different types of amino acid changes in the CYP81A9 sequence are associated with variation in nicosulfuron injury. Reynoso et al. [205] also demonstrated the potential genotoxic activity of nicosulfuron and topramezone, which can induce genetic damage to field and sweet corn. Atrazine is a widely used herbicide in processing sweet corn. However, its use has been restricted in some areas. Arslan et al. [206] researched weed management alternatives to atrazine in processing sweet corn. They found that timely interrow cultivation in atrazine-free treatments were not able to control weeds. Postemergence treatments with tembotrione, with or without interrow cultivation and postemergence treatments with topramezone efficiently controlled small-seeded weed species.

Other options include the development of alternative herbicides with lower environmental impact; however, the process is not straightforward. For example, Do-Thanh et al. [207] designed multistep synthesis compounds bearing combinations of functional groups associated with auxin-type properties, though they were not as active against weeds in sweet corn as commercial herbicides are. Paporisch and Rubin [208] studied the mechanism of response and the heritability of susceptibility to P450-metabolized herbicide used in sweet corn, namely, foramsulfuron, iodosulfuron, rimsulfuron, and tembotrione, and found that foramsulfuron selectivity is associated with P450 metabolism and that isoxadifen positively affects P450 activity. The sensitive genotype that does not respond to isoxadifen is presumably homozygous for a deficient or non-functioning P450 gene.

Some authors reported nutritional benefits of using herbicides. Disruptions in biochemical pathways in plants due to the application of herbicides, safeners, or other pesticides have the potential to alter the nutrient quality, taste, and overall plant health associated with edible crops. Mesarovic et al. [209] stated that the P450 affecting herbicides nicosulfuron and mesotrione, with and without foliar fertilizer, improved the nutritive profile of the sweet corn kernel as the concentration of carotenoids, tocopherols and free phenolic acids increased, though these effects were genotype-dependent. Cutulle et al. [210] evaluated the effects of some herbicides in sweet corn and found that several herbicides increased the uptake of the mineral elements phosphorus, magnesium, and manganese. All herbicides in their study increased protein content. Nicosulfuron produced similar levels of saturated, monounsaturated, and polyunsaturated fatty acids alone but, when applied with isoxadifen-ethyl, increased fatty acids. Nicosulfuron plus isoxadifen-ethyl or topramezone or the combination of all three increased the concentrations of fructose and glucose while reducing levels of maltose or sucrose.

Besides the intrinsic characteristics of a herbicide, is efficiency depends also on environmental conditions and application methods. Harris et al. [211] showed that manuka oil had very weak preemergence weed control, caused minimal crop injury, and provided good postemergence weed control, particularly when manuka was used as a tank-mix partner for crop yield and weed control.

7.2. Mulching

Plastic mulch is used with many vegetable crops to limit weed growth and for its potential to decrease days to harvest and maintain soil moisture, but the residues left by plastic are a major environmental concern, coupled with the costs involved. Ghimire et al. [212] compared five plastic soil-biodegradable mulches and paper mulch with black polyethylene. They found that growth, yield, and quality of sweet corn grown with black plastic biodegradable mulches was comparable to black polyethylene mulch, making black plastic biodegradable mulches an effective alternative to standard black plastic mulch for sweet corn production in a Mediterranean-type climate. Nurse et al. [213] tested living mulch/herbicide pairings (adzuki bean: linuron + S-metolachlor, cereal rye: saflufenacil, and oilseed radish: pendimethalin) and an industry standard (S-metolachlor/atrazine). The most effective annual grass control for sweet corn over-seeded with living mulches alone was the cereal rye, and the combination of adzuki bean plus herbicide was the most effective for annual grass suppression. However, marketable yields in all living mulch treatments were below the industry standard. Martin-Closas et al. [214] studied the agronomic effects of degradable bioplastics used as agricultural films. The film improved yield, earliness, product quality, and weed control efficacy. Microclimatic improvement and film soil coverage and degradation are also important considerations for crops not so frequently mulched, like sweet corn.

7.3. Cover Crops

Cover crops can help to control weed prevalence in cash crop systems and contribute to sustainability of the production systems but herbicide residue can be a complicating factor. Rojas et al. [215] reported that though herbicide residues reduced roots, differences in aggregate size, wet aggregate stability, and aggregate size plus soil mineral N were not significant. Anesio et al. [216] reported that cucumber, pigeon pea, and alfalfa were most susceptible to the auxin herbicide residues. However sweet corn and sorghum showed lower chlorophyll content in soils with 2,4-D+ picloram residual up to 80 days after application of herbicide.

7.4. Agronomic Management

Weeds can be controlled with appropriate variety choice and adequate agronomic management. Boydston and Williams [217] stated that less intense weed management resulted in more weeds. Cultivation of taller sweet corn hybrids with greater leaf area maintained crop yields better than shorter, less competitive sweet corn hybrids. Strip-intercropping of functionally diverse cover crop mixtures is one mechanism by which nitrogen banding can be applied to an organic, strip-tilled system to increase crop competitiveness over weeds. Lowry and Brainard [218] hypothesized that by targeting hairy vetch to the tilled strips directly in row with future crop establishment and cereal rye to the untilled strip directly between future crop rows would benefit the crop nitrogen availability. As vetch biomass increased, nitrogen was more available for sweet corn; however, vetch biomass across the whole plot was more efficient for sweet corn nutrition than rye and vetch segregation into strips. Proper timing for weeding is of paramount importance for optimizing labor and results. Simarmata et al. [219] determined the critical period of sweet corn for weed control under a tropical organic farming system. Plant height, leaf area, and yield of sweet corn were proportional to the variation of weedy and weed-free periods. The critical period of the crop for weed control was from 3 to 53 days after planting, but the critical period varies with the target environment. In Turkey, Tursun et al. [220] determined that, for sweet corn, the critical period for weed control ranged between the V2 and V10 growth stages, which implies that weed management should be initiated around the V1 stage and maintain a field without weeds through the V12 stage to prevent significant yield losses. Brown [221] implemented several organic weed management strategies including cultivation of weed seedlings during the early, weed-sensitive critical period of the crop, frequent cultivation events to ensure zero seeds, and weed suppression with polyethylene or natural mulches. Adoption of conservation tillage practices has been slow in organic vegetable production, partially due to producers' concerns regarding weed management. Integrating cover crops into a conservation tillage program may provide organic producers a viable weed management option enabling growers to practice conservation tillage. Chen et al. [222] demonstrated that there is a potential to use strip tillage integrating with a stale seedbed tactic for weed management in organic sweet corn, reducing herbicide use, hand-labor, and cost of weed management while maintaining yield.

As hand weeding has high labor costs, some researchers are trying to develop automatic weeding systems. Jasinski et al. [223] checked the vision system for plant and weed classification testing an autonomous robot for sowing and wide row sowing. Positive test results will allow for the use of the robot in organic crops requiring mechanical removal of weeds or in crops with application of selective liquid agrochemicals limited to the minimum.

7.5. Early Vigor

Early vigor is an indirect method of weed control because vigorous corn competes with weeds for nutrients and light. However, the defective mutants used for sweet corn production have limited vigor. Additionally, vigor is generally assessed with subjective scales as it cannot be accurately predicted by objective methods such as recording weight and color or measuring conductivity of seed, and some of those methods are destructive.

Zhang et al. [224] proposed using visible and near-infrared hyperspectral imaging to detect the electrical conductivity of sweet corn seeds, which has optimal performance and high correlation with conductivity in sweet corn seeds.

8. Models and Production

Sweet corn is a high input, high value seasonal vegetable crop that can command high prices, especially when produced under organic conditions. However, crop area is limited in most countries because of challenges of successfully producing sweet corn under organic agriculture. Sweet corn requires high levels of fertility, irrigation, and intensive pest management techniques to control weeds and insects. As the production costs can be high, optimizing the system is a key step for increased adoption of the crop.

8.1. Prediction Models

There are various approaches to the development of predictive models for agricultural production. One alternative is based on modeling yield using crop cultivation parameters. Another alternative involved developing models with yield components and agronomic traits. Lykhovyd [225] compared a conventional technological approach with an approach based on yield modeling in sweet corn in southern Ukraine. The methods proved equally accurate and reliable; however, the yield-based model provided better yield predictions than the technological model. Some models are devoted to a target region. Lykhovyd et al. [226] investigated sweet corn leaf growth and development under diverse crop cultivation procedures, such as plowing depth, rate of mineral fertilizer application, and planting density, in the drip-irrigated conditions of southern Ukraine. They found significant effects for all the studied agro-technological treatments. Increased plowing depth improved the leaf area index of sweet corn only under non-fertilized conditions; however, increased fertilization and plant density positively affected the biometric index. Lykhovyd et al. [227] determined the accuracy and reliability of yield models for semi-arid conditions on the dark-chestnut soil in southern Ukraine with two different indices—the leaf area index obtained through direct surface measurements and the normalized difference vegetation index obtained through spatial remote sensing. Additionally, they developed mathematical models for crop yields estimation based on regression analysis. Leaf area index was suitable for crop yield prediction and remote sensing had no benefits.

Other models mainly focus on economic calculations. Ghazaryan et al. [228] developed a hedonic pricing model for analyzing the influence that product attribute levels have on prices for sweet corn and other crops. That model allows for the extrapolation of prices from one location to other markets. Furthermore, vendors and other direct marketers can use attribute pricing information to identify the quality attributes that consumers prefer. Adiyoga et al. [229] examined the economics of vegetable production, including sweet corn, in Indonesia. The two main factors affecting farmers' income are production and price. Many of the farmers studied preferred less risk with correspondingly lower profits. In their area of study, collective marketing could strengthen farm–market linkages.

There were also theoretical modelling studies using sweet corn as reference crop. Linear regression is a classical tool, while artificial neural networks are a comparatively new one. Lykhovyd [230] determined whether artificial neural networks are more accurate than linear regression in sweet corn yield prediction in Ukraine. They studied the impact of moldboard plowing depths, mineral fertilizer application rates, and plant densities on the crop yield. Artificial neural network prediction was more accurate than the linear regression model.

Reid [231] developed a model to assist forecasting and interpreting sweet corn under optimal mineral nutrient supply. Leaf area growth was calculated using a discrete logistic equation that included adjustments for soil water deficit. Leaf senescence depends on age and drought. The conversion efficiency for intercepted radiation to biomass also varied with drought. Ear dry mass was computed assuming harvest index varying linearly with thermal time. Model performance was most accurate for leaf area and biomass, followed by ear dry mass. Confalonieri et al. [232] developed a smartphone app for precision measurements of leaf angle and curvature, which are related to plant productivity. Repeatability and reproducibility were similar for the different methods, with the exception of the digital inclinometer, which was less precise.

Rosa et al. [233] determined the effect of weather components (air temperature, precipitation) on the growth, yield, and length of growing season of sweet corn cultivated in eastern Poland. Weather conditions significantly modified the yield of ears, weight, number of marketable ears, plants height and length of growing season. Moderate air temperatures in July and uniform distribution of precipitation during the growing season raised sweet corn yield.

8.2. Cultivation Models

Isaak et al. [234] compared two methods to evaluate the mechanization status of field operations in sweet corn cultivation in Malaysia. The first method used the PCL-HRL-EGL Cartesian plot based on production capacity, heartbeat rate, and energy expenditures of human labor. The second method was a mechanization index based on energy expenditures of machinery and human labor. These methods could allow the optimization of resources for mechanization of sweet corn cultivation. Laosutsan et al. [235] investigated the factors affecting decisions for adopting good agricultural practices in sweet corn in Thailand. Income was the most influential factor and the authors recommended that the government agencies create a certificate of good agricultural practices. Khan et al. [236] reported changes in growth parameters of sweet corn under different micro-environments in Pakistan induced through altered planting dates. Maximum leaf area index, absolute growth rate and crop growth rate were reached when planted in July, whereas maximum plant height and plant dry weight were recorded in earlier plantings.

Some of the models manage advanced technology; for example, Layden and O'Halloran [237] determined whether significant spatial variability in crop performance exists in Australia, and if it can be managed to improve marketable yield of vegetables, including sweet corn. Precision technology would improve input management by detecting early crop stress from biotic and abiotic factors allowing for targeted chemical programs in order to improve marketable yields. The authors used Greenseeker biomass sensors along with remote sensing in collaboration with vegetable producers. Owen and LeBlanc [238] examined methods for high quality sweet corn production in long term organic rotations in Canada. Techniques included transplanting instead of direct seeding, planting into zone-tilled established red clover living mulch, narrow over-zone biodegradable organic mini-mulches, drip irrigation, fertilization with pre-plant banded organic compost and soluble organic fertigation, and pest control with organic pesticides. They found that such high-performance systems could be profitable in Canada and offer a reliable system for producing organic sweet corn. Other models focus on specific agronomic practices, such as irrigation methods. Moteva et al. [239] established irrigation scheduling parameters of sweet corn for drip and sprinkler irrigation for optimizing yield and yield components. Drip irrigation establishes better conditions for green biomass development, while sprinklers improved conditions for productivity.

8.3. Cropping Systems

Sweet corn has high added value and can be the main crop, but it can be also used as a catch crop, as previously shown, or in intercropping systems. Lauriault et al. [240] analyzed sweet corn, oats, and turnip (brassica) for forage value. Intercropping with turnip improved sweet corn stover in vitro dry matter disappearance and increased animal gains compared to corn alone due to additional crude protein. Intercropping oat or turnip with sweet corn is viable for improving sweet corn stover for fall forage; in addition, turnip had a positive effect on stover nutritive value. Manjunath et al. [241] compared sweet corn intercropping with rice with other alternatives and found that sweet corn-rice had the highest rice equivalent yield and the highest potential usable residue for the west coastal region of India under protective irrigation. This combination also had the highest energy ratio, specific energy, and energy productivity. The rice–sweet corn system was the most productive, economical, and energy efficient cropping system. Sharratt and Collins [242] assessed the potential protection against wind erosion of irrigated potato–sweet corn rotation under conventional and reduced tillage. Soil loss was greater from potato than sweet corn and from conventional than reduced tillage systems. Differences in soil loss were likely due to differences in residue cover and silhouette area. They concluded that cover crops should be established soon after harvest and reduced tillage practices adopted to protect the soil from wind erosion in the Columbia Basin. Khan et al. [243] reported agronomic characteristics of landraces under different microclimatic regimes in Pakistan. Maximum internode length was obtained under early planting, whereas maximum number of leaves, ear length, kernels/ear, and 1000-kernel weight were recorded from July plantings. Williams [244] studied the effect of plant density and hybrid on the reproductive sink of sweet corn and optimal plant densities for *sh2* sweet corn. Current seeding rates have optimized the reproductive sink size for today's white kernel *sh2* hybrids. Mehta et al. [245] identified that suitable sowing and harvest times were important for achieving high kernel sweetness and yield for successful. Average sweetness across harvest dates attained the highest value in the third sowing and 24 days after pollination recorded the highest brix across sowing dates. Sowing time affected cob and fodder yield, and third sowing was identified as the most favorable environment for both traits but kernel sweetness was not associated with cob and fodder yield. Promkhambut et al. [246] analyzed environments in northeast Thailand, comparing physical and social factors of field crops and vegetables, concluding that sweet corn could replace rice in order to improve farmers' income. However, the available area for multiple cropping is limited by irrigation availability and soil texture, as well as social and economic factors such as4 availability of markets. Lowry and Brainard [247] found that strip tillage and strip intercropping were positive for adapting reduced tillage for organic production. Strip tillage reduced soil inorganic N compared to full tillage, but increased soil moisture and sweet corn shoot biomass. Belfry and Van Eerd [248] assessed timing of cover crop intersowing into standing corn and utility of alfalfa and 17 other cover crops species or multispecies mixes. They found that corn yield was not affected. Sweet corn cover crop treatments exhibited poor stands of limited growth at corn harvest, attributed to sweet corn canopy closure. Hairy vetch, oilseed radish, and three of six cover crop blends accumulated important amounts of dry biomass by corn harvest. Cover crops interseeded in hybrid seed corn production systems have little risk and provide ground cover during postharvest fallow periods.

8.4. Variety Testing

Practical evaluations of varieties for potential commercial value in target environments are currently carried out by several researchers. Hikam and Timotiwu [249] explain the requirements for cultivating sweet corn in acidic, red–yellow Podsolic soil in Indonesia with low fertility and pH. Soil amendments and selecting for adapted cultivars can improve production. However, since the genetic variation of the available germplasm was not appropriate, external sources of genetic diversity are required. Pereira et al. [250] described the main traits of two supersweet corn cultivars, which produced higher yields than the control cultivar in northern and northwestern Rio de Janeiro State (Brazil). Soare et al. [251] studied sweet corn hybrids cultivated in Romania for identifying hybrids with good quantitative and qualitative yield. Surtinah and Nurwati [252] evaluated several sweet corn varieties to help in choosing the best varieties for sustainable food production in Indonesia. Williams [253] determined the pattern of genotype adoption and use of processing sweet corn in relation to yield and stability for decision-making on genotype choice. Stable production across environments is a more important trait for sweet corn processors than a genotype with high yield under favorable conditions. This conclusion is consistent with the industry's need to have a predictable level of performance in the processing facilities in the northern United States. Mehta et al. [254] evaluated supersweet corn genotypes at three sowing and harvest dates. Genotype, sowing time, and harvest time had a significant influence on kernel sweetness. The genotype x sowing time and genotype x harvest time interactions were significant as well. Sowing time also affected cob and fodder yield and anthesis. Late sowing favored kernel sweetness and cob yield. Cob and fodder yield were positively correlated, but they were not correlated with kernel sweetness. Nazli et al. [255] determined the optimum harvest stage of four corn varieties for silage production, including sweet corn, in Malaysia. Sweet corn had the highest performance when harvested early due to high dry matter yield, digestibility, energy content and low fiber. However, financial analysis showed that sweet corn production was not financially feasible.

9. Nutritional Value and Quality

Sweet corn is a popular food in the US and its popularity is spreading around World. However, it is not always easily accepted by people that lack corn in their cultural habits. For example, Dinnella et al. [256] reported sensory evaluation of canned vegetables among adolescents from Denmark, France, Italy, and the United Kingdom. Canned sweet corn was classified in a group of highly disliked vegetables, along with cauliflower and broccoli, characterized by disliked sensations of objectionable flavors because of bitter and sour tastes. This finding is likely an artifact of processing. Fresh sweet corn is seldom described as bitter or sour.

There is much variation in nutrient composition among maize types, uses, and products. Prasanthi et al. [257] compared fresh and cooked baby corn, sweet corn, field corn, and industrially processed and cooked popcorn, corn grits, corn flour, and corn flakes for minerals, xanthophylls, and phenolic acid content. Compared to popcorn, the other maize products had higher concentrations of magnesium, phosphorus, potassium and lower concentrations of calcium, manganese, zinc, iron, copper, and sodium. Popcorn was high in iron, zinc, copper, manganese, sodium, magnesium and phosphorus. The xanthophylls lutein and zeaxanthin were more abundant in field corn and the total polyphenolic content was highest as well. The distribution of phenolic acids was variable in different corn products. Preparation and processing reduced xanthophylls and polyphenols in general.

Quality of fresh sweet corn decreases rapidly, particularly if stored at high temperatures. Xie et al. [258] found that higher storage temperatures increased respiration rates. As storage temperatures increased, sensory evaluation, soluble sugars, vitamin C, and soluble protein decreased as did the wet weight. To maintain best quality, sweet corn should be stored at 0 °C. Forced air cooling and low temperature transportation are needed to provide quality sweet corn. Xie et al. [259] reported that the optimum retailing storage condition was under 4 °C. They found that sensory evaluation, weight loss, soluble sugar content, vitamin C content, and soluble protein content of sweet corn significantly differed under different retail conditions. Therefore, sweet corn should be processed as rapidly as possible after harvest. In order to manage postharvest handling, methods of classification of sweet corns based on storage time after harvest were developed by Suktanarak et al. [260]. They used near infrared reflectance as methods of classification and established and validated a classification model. The predictive accuracies for unhusked and husked sweet corns were high, indicating that the model was reliable.

9.1. Antioxidants, Vitamins, and Minerals

Sweet corn is a source of antioxidants and other phytochemicals such as melatonin and tryptophan. Melatonin upregulates the expression of brain-derived neurotrophic factor gene enhancement of nerve cell function and mediation of anti-aging effect of the brain cells. Chumpiya et al. [261] determined that rice and corn extracts may protect cells against hydrogen peroxide-induced neurotoxicity.

Das and Singh [262] explain that quality protein maize, baby corn, popcorn, and sweet corn are sources of phenolic antioxidants. They have vanillic, syringic, p-hydroxybenzoic, caffeic, p-coumaric, ferulic, and isoferulic acids along with cyanidin-3-O-glucoside, kaempferol and quercetin. Most free phenolic compounds are in the germ and most bound ones in the pericarp. Baby corn and sweet corn have high free phenolics and sweet corn has high lipophilic tocochromanols. Zhang et al. [263] reported that total phenolic content differs significantly among sweet corn varieties.

Phytochemical content in sweet and waxy corn depend on several factors including genotype and maturation stage. Song et al. [264] compared carotenoid composition of sweet and waxy corn kernels at milk and dough stages. Waxy corn kernels had less total carotenoids content than sweet corn kernels. Moongngarm et al. [265] evaluated five commercial sweet and waxy corn cultivars for phytochemical composition at milk, late milk, and soft dough stages. Total phenolics and total anthocyanins were highest in the dark purple waxy variety, with cyanidin as the main anthocyanin. Carotenoids were also affected by endosperm type and timing of harvest. Yellow sweet corn had high levels of carotenoids, with lutein the main type. Levels of gamma-tocotrienol, gamma-tocopherol, and alpha-tocopherol also were affected by harvest timing.

Flavonoids have diverse biological functions in human health. C-Glycosylflavones are neuroprotective against beta-amyloid-induced tau hyperphosphorylation and neurotoxicity in SH-SYSY cells, which are relevant to Alzheimer's disease prevention and treatment. Zhang et al. [266] reported that the content of the flavonoids eriodictyol, luteolin, isoorientin, and maysin varied in pollen, silks, tassels, and seeds among five maize varieties. Eriodictyol content was high in pollen, isoorientin content was greater in pollen and tassels, and maysin content was high in silks and tassel. The differential expression of five genes involved in maysin biosynthesis correlated well with the profiles of the four flavonoids among tissues and varieties.

Song et al. [267] characterized eight principal carotenoids during kernel development in a field and a sweet corn variety. There were similar trends in the amounts of total carotenoids. Violaxanthin, zeaxanthin, lutein, alpha-cryptoxanthin, and beta-cryptoxanthin contents had upward trends in both cultivars, whereas neoxanthin content declined. In the field corn variety, there were highly significant positive correlations between deeper yellow-orange color and zeaxanthin, lutein, and violaxanthin content. Correlations with color were weaker in sweet corn.

Genetic variation exists for carotenoid accumulation in sweet and field corn kernels. Liu et al. [268] analyzed carotenoid profiles, expression patterns of carotenogenic genes, and antioxidant activities during kernel development in two genotypes of sweet corn. They found at least five genes involved in carotenoid synthesis and two stages for carotenoid accumulation during kernel development. Baseggio et al. [269] performed a genome-wide association study of seven kernel carotenoids and twelve derivative traits in a sweet corn inbred line association panel to identify genes associated with natural variation for carotenoid content. In agreement with earlier studies of maize kernels at maturity, they found an association of β-carotene hydroxylase (crtRB1) with β-carotene concentration and lycopene epsilon cyclase (lcyE). Additionally, they found that 5% or fewer of the evaluated inbred lines with *sh2* endosperm had the most favorable lycE allele or crtRB1 haplotype for elevating β-branch carotenoids (β-carotene and zeaxanthin) or β-carotene, respectively.

Sweet corn is an important source of provitamin A for humans. Vitamin A deficiency damages the immune system and may cause blindness, particularly in children in developing countries where food availability is limited. A solution is biofortification of the crops used as dietary staples, such as maize. Biofortification provides a sustainable way to prevent Vitamin A deficiency and other micronutrient malnutrition problems. Yang et al. [270] used a field corn line as the donor parental line for four elite sweet corn lines as recipient lines by marker-assisted selection and the results were a successful increase in provitamin A in the sweet corn lines.

Anthocyanins are important phytochemicals but are generally expressed at the green corn stage in sweet corn. However, they are strongly expressed in many waxy corns and there are some new sweet corns with strong expression of anthocyanins at the fresh stage. Hong et al. [271] developed an ultra-high-performance liquid chromatography-diode array detector-mass spectrometry method for characterization and quantification of anthocyanin components in complex corn–kernel matrices. They identified eighteen anthocyanins, with cyanidin-based glucosides as the major pigments of purple-pericarp sweet corn and blue-aleurone maize. Pelargonidin-based glucosides were the main anthocyanins of reddish–purple-pericarp sweet corn and cherry-aleurone maize. Hong et al. [272] studied the anthocyanin profile of purple supersweet corn developed from purple Peruvian maize and the effect of kernel maturity on anthocyanin accumulation. They identified 20 anthocyanin compounds, consisting of cyanidin-, peonidin-, and pelargonidin-based glucosides in purple- and reddish–purple-pericarp sweet corn. During kernel maturation, pigment in the pericarp formed first at the silk attachment gradually spreading over the entire kernel.

Antioxidants vary during postharvest management and processing. Xiang et al. [273] studied the phytochemical profiles of sweet corn kernels during preservation and elaborated the effect of thermal processing for guidance in the process and preservation of post-harvest fresh kernels of phenolics, vitamin E, and antioxidant activity in sweet corn kernels. Vitamin E (tocopherols and tocotrienols) is a lipid soluble antioxidant in sweet corn kernels, providing healthy nutrients to both plants and humans. The key genes involved in the vitamin E biosynthesis pathway have been identified in plants. Xiao et al. [274] investigated the genetic architecture of vitamin E content in sweet corn kernels in an association panel of 204 inbred lines of sweet corn. They quantified seven compounds of vitamin E in fresh sweet corn kernels regulated by 119 loci. Furthermore, they proposed candidate genes involved mainly in RNA regulation and protein metabolism.

Sweet corn varies for tocochromanol (tocopherol and tocotrienol) levels but makes only a limited contribution to daily intake of vitamin E and antioxidants. Baseggio et al. [275] performed a genome-wide association study of six tocochromanol compounds and 14 derivative traits in a sweet corn inbred association panel to identify genes associated with natural variation for tocochromanols and vitamin E in fresh kernels and found some genes that can be helpful in prediction models for improving the nutritional and healthy value of sweet corn.

One of the most studied phenolics metabolites is ferulic acid, which is an outstanding antioxidant agent very common in vegetables, such as sweet corn. Chaudhary et al. [276] reported that ferulic acids have a wide scope of effects against human diseases including malignant cancer, diabetes, and cardiovascular and neurodegenerative diseases. Chudhangkura et al. [277] investigated the effects of pre-canning treatments such as ultraviolet C, controlled atmosphere, and ultrasound, on the free ferulic acid (FFA) content, texture, and color of canned sweet corn kernels. Maize irradiated with ultraviolet and stored under modified atmosphere had the highest free ferulic acid content. Maize treated with ultrasound combined with the two selected ultraviolet C and controlled atmosphere treatments showed no differences in ferulic acid content, moisture, texture, or color. Maize kernels treated with ultraviolet C, controlled atmosphere, or ultrasound had higher free ferulic acid content than untreated kernels. Thus, these pre-treatments appear to be alternative processes that might add value to canned sweet corn kernels by increasing FFA content.

Many factors, in addition to genetics, can affect kernel composition, including environment and plant tissues. Calvo-Brenes et al. [278] reported kernel position effects on zeaxanthin, lutein, total carotenoid, and quality parameters in a zeaxanthin-biofortified sweet corn, though the effect is less than the influence of genotype and kernel maturity. Yang et al. [279] investigated phytochemical profiles and antioxidant capacity in ear sections of sweet corn and found that diverse ear sections of sweet corn, besides kernels, had high antioxidant capacity. Ear sections are used for frozen cobbettes, which are popular at USA restaurants and show promising potential worldwide. Xie et al. [280] reported that vitamin E in sweet corn increased during kernel development and reached the highest level at 30 days after pollination with the content of gamma-tocotrienol highest, followed by gamma-tocopherol. The content of isomers gamma-tocopherol, alpha-tocotrienol, delta-tocopherol, delta-tocotrienol, and beta-tocopherol were followed during kernel development. The antioxidant activity of sweet corn during kernel development increased, associated with the increase in vitamin E. Liu et al. [281] found that light and dark environments affected the expression of genes that affected vitamin C, E, and folate biosynthesis pathways during germination. Levels of vitamin C and folate increased during germination of sweet corn kernels while vitamin E declined. Sweet corn sprouts had more vitamin C and E levels as well as relevant gene expression levels in a light environment, while illumination had little influence on folate content and gene expression levels during germination. They concluded that there might be a collaborative relationship between vitamin C and folate regulation during sweet corn seed germination, while an inhibitive regulation might exist between vitamin C and E.

Besides biomolecules, minerals obtained from sweet corn are important for human health. In sweet corn embryos Zn is accumulated mainly as Zn-phytate, whereas endosperm Zn is complexed with a N- or S-containing ligand, possibly as Zn–histidine and Zn–cysteine [282]. These authors found that the majority of the Zn was in the endosperm and pericarp. This suggests that whilst the Zn in the endosperm and pericarp is likely to be bioavailable for humans, the Zn in the embryo is of low bioavailability.

Grain yield and nutrient concentration are usually inversely correlated, posing a serious challenge for biofortification; however, in sweet corn the concept of yield is not just dry matter but the number of marketable fresh kernels or ears. Furthermore, when the objective is to maximize nutrient production, some compromises are possible. Cheah et al. [283] reported that, although there was a negative correlation between the number of kernels per cob and kernel Zn concentration, total kernel Zn accumulated per cob increased with increasing kernel number. Therefore, obtaining high kernel Zn concentrations and high yield in sweet corn is still a challenge.

9.2. Processing

Sweet corn can be eaten fresh or in a variety of processed forms, such as cooked, frozen, canned, or juiced. Blanching is a common treatment for conservation. Blanching inactivates enzymes and can be performed using microwave, steam, or hot water methods. Szymanek et al. [284] determined the influence of blanching time on moisture content, sugars, protein, and processing recovery of sweet corn kernels. Blanching time has significant influence on the content of moisture, sugars, and protein in kernels as well as on quantity of cut kernel mass. Kachhadiya et al. [285] compared microwave, steam, and hot water blanching methods and studied their effects on enzymatic activity and chemical and physical properties of sweet corn. They found reductions in peroxidase activity, total sugars, ascorbic acid, moisture content, and kernel mass. Retention of total sugar and ascorbic acid was highest in microwave blanching.

Freezing affects carotenoid content and quality parameters in zeaxanthin-biofortified and commercial yellow sweet corn. Calvo-Brenes and O'Hare [286] observed that, in cobs frozen and stored at −20 °C, carotenoid concentration decreased. Conversely, freezing at -80 °C did not affect carotenoid concentration for ears stored up to three months. Storage at 4 °C was adequate for carotenoid retention up to fifteen days and served as a preconditioning temperature to avoid the detrimental effects of storing cobs at −20 °C. Color and starch content were not affected by storage at 4 °C for up to fifteen days; however, sugars and total soluble solids declined. On the other hand, Song et al. [287] reported that color decreased and vitamin E increased in sweet corn juice due to thermal treatment. Carotenoid content changed with high temperature, although degradation of carotenoids in sweet corn juice was limited. Song et al. [288] showed that increasing temperature gradually decreased concentrations of total and trans carotenoids in sweet corn juice. Reduced concentration of total cis carotenoids was related to formation of some oxidative products and volatile compounds in sweet corn juice. It appears that these aromatic compounds are produced by degradation of carotenoids.

Sitthitrai et al. [289] processed Naulthong, a new hybrid bicolor mini-ear supersweet corn. Boiling caused more effective heat transfer and leaching, decreasing total soluble solids. Atmospheric-steamed kernels had higher levels of lutein, zeaxanthin, ferulic acid, total phenolic contents, and antioxidants than those of pressure-steamed and boiled kernels. Boiling resulted in reduction in antioxidants. Steaming at normal pressure, rather than at high pressure, is recommended for cooking corn to maximize health benefits from the delivery of bioactive compounds.

Processing entails additional cost and impacts. Consumer awareness regarding the ecological benefits of green products and services is increasing. Manufacturers are paying more attention to environmentally friendly production, life cycle assessment, and ecological footprints. Usubharatana and Phungrassami [290] determined the damage to the environment of canning sweet corn. Processing, packaging, and steaming of corn kernels contributes significantly to the ecological footprint of a single can of corn.

9.3. Food Toxicity

Food toxicity can originate in several ways, one being contamination with heavy metals (Pb, Cd, As, Fe, Mn and Zn) or nitrate and nitrite in food processing. Ainerua et al. [291] found varying concentrations of nitrates, nitrites, and heavy metals in all canned food categories sampled in Nigeria which exceeded recommended limits set by EU. While Fe, Mn, and Zn are required in the diet, excess levels can create health risks. Health risk assessments based on estimated daily intake values for Cd in canned food categories were above the tolerable daily intake, while dietary exposure for Fe in canned sweet corn, Fe, Zn and Pb in canned beans/peas had values above recommended limits

Heavy metal contaminants in agriculture are environmental problems because they affect food safety; consequently, several researchers investigated the absorption of Pb, Cd and Cu by plants and, how to reduce absorption by using organic chelating agents like humic and fulvic acid in manure. Priyadi et al. [292] showed that exposure of Pb and Cd in sweet corn and soybean seeds were undetectable, while exposure of Cu in sweet corn seeds was low. Contamination of Pb, Cd, and Cu exposures in soil after sweet corn harvested were high, undetectable, and high, respectively. As poverty, malnutrition, and unemployment are increasing with intensive urbanization, urban agriculture offers a solution for food production if space and water are available. The definition of a hazardous class of heavy metals depends on the response of the plant and degree of contamination. Maize can be used both as an indicator plant and as a natural filter for areas with potential risk of contamination with heavy metals. Sukiasyan [293] assessed the environmental risk factor of diverse heavy metals in various soil and climatic regions and concluded that standard protocols are needed for classifying heavy metals by hazard class according to the maximum allowable concentration. Cao et al. [294] evaluated the efficacy of using maize for accumulating arsenic in contaminated soils in China and concluded that the concentration of arsenic in maize kernels was lower than for other crops, with waxy corn more appropriate than sweet corn based on their concentration levels specifically. He et al. [295] suggested that oxidative proteins from Arabidopsis might be involved in stress tolerance and stress escape, such as Cadmium, explaining the possible mechanism and suggesting the candidate gene homologous of ZmOXS2b to engineer stress tolerance.

Trace elements are a large concern for human health. Aguilar et al. [296] compared the concentrations of arsenic, copper, and zinc in the edible parts of vegetables, including sweet corn. The crops were grown in a mining–agricultural area and in an exclusively agricultural area and potential human health risks of consuming vegetables from both areas were evaluated. The consumption habits of the studied population were extracted from the 2010 National Alimentary Survey of Chile. The concentrations of trace elements in the edible tissues of vegetables were higher in the mining–agricultural area than those in the control area, particularly for leafy vegetables, with arsenic being of the greatest concern.

9.4. Mycotoxins

Mycotoxins produced by fungi can cause fatal diseases in animals and humans. Therefore, regulatory limits for mycotoxin contamination in food and feed have been imposed in many countries. Among the most common fungi attacking sweet corn, Fusarium species are toxigenic, systemic pathogens in sweet corn. Detection is a challenge because routine methods are expensive and time consuming, though new methods are being developed. Kaltner et al. [297] presented a sensitive, valid, cost-effective, and easily transferable analytical method for quantitative determination of the relevant fumonisins B-1 (FB1) and B-2 (FB2) in maize products. The method is based on reversed-phase high-performance liquid chromatography with fluorescence detection.

Ridout et al. [298] demonstrated that fungal antagonists of seedborne Fusarium alter production of Fusarium mycotoxins directly or systemically. *Pichia membranifaciens* and *Penicillium griseolum* reduced fumonisin production by *F. verticillioides*, while *P. membranifaciens* and *Penicillium sp.* reduced fumonisins produced by *F. proliferatum*. Pre-planting inoculation of seeds with Penicillium systemically increased fumonisins. *Morchella snyderi* applied to silks systemically reduced deoxynivalenol. Antagonists did not suppress Fusarium in mature kernels following silk inoculations. Fusarium mycotoxin concentrations in sweet corn kernels were changed by fungal antagonists. The Mexican tamal and the Brasilian pamonhas can be made with sweet corn and can contain fumonisins. Silva et al. [299] found fumonisin contamination in some of the samples above the national maximum level. Furthermore, pamonhas were a favorable substrate for fungal growth. Al Momany et al. [300] evaluated the effect of treated wastewater on the development of Fusarium wilt of sweet corn. Irrigation with treated wastewater decreased the development of Fusarium stalk rot disease of sweet corn. The concentration of most elements was higher in treated wastewater treatments than in potable water treatments. Trace and heavy metals showed elevated levels in soil samples obtained from plants irrigated with treated wastewater at different depths. Irrigation with treated wastewater improved plant growth, reduced fertilizer application, and increased productivity of poor soils.

Vegetables contaminated with human pathogens represent a risk for consumers, especially when consuming unprocessed vegetables. Fresh vegetables can become contaminated with Listeria by contaminated soil, manure, or irrigation water. Kljujev et al. [301] found Listeria spp. and L. monocytogenes in sweet corn and other vegetables. Wit et al. [302] studied Fumonisin FB1 content in sweet corn kernels. Infection degree of sweet corn was stronger than infection of popcorn ears, though the most dynamic increase in fumonisin FB1 biosynthesis was observed in popcorn kernels.

One of the most promising management tools to reduce mycotoxins in food and feed is pre-harvest biological control of mycotoxigenic fungi using microbes. Sivparsad et al. [303] found that the T77 strain of Trichoderma harzianum was efficient for controlling *Aspergillus flavus* on sweet corn and reducing aflatoxin contamination. Antibiosis and mycoparasitism are the probable modes of action of T77. Sivparsad et al. [303] proposed an integrated approach consisting of pre-harvest biological control using selected strains of T. harzianum in conjunction with other post-harvest management strategies for reducing *A. flavus* infection and aflatoxin contamination in the kernels. Huang et al. [304] published an improved method for measuring aflatoxin content in sweet corn at early stages. They used an improved electronic nose with a competitive direct enzyme-linked immunosorbent assay. They concluded that the improved method had excellent performance as it has a rapid, easy operation, low cost, and effective method to quantify aflatoxin content in sweet corn at early stages.

9.5. Seed Quality

As sweet corn is based on defective starch synthesis mutants, seed quality is always a concern. In fact, as table quality (tenderness and high sugars) increases, there is an inverse effect on seed quality as measured by germination rates and seedling vigor. Furthermore, combinations of two or more starch synthesis mutants often improve table quality of sweet corn, though result in a concomitant decrease in seed quality. Pairochteerakul et al. [305] found that the single recessive genotype (*sh2sh2*) had high germination percentage and seedling vigor. However, combinations of *bt2* or *sh2* genes with the *waxy1* (*wx1*) gene resulted in low germination percentage and poor seedling vigor.

Another aspect of seed quality is purity, defined as the ratio of seeds belonging to a specific cultivar to the total seeds tested, which is a requisite for commercial seed quality. However, conventional methods for determining seed quality are time-consuming, expensive, and destructive. Qiu et al. [306] suggest the use of a non-destructive method based on Fourier transformed near-infrared spectroscopy combined with discriminant analyses as a feasible way to classify sweet corn seed cultivars and select high-purity seeds.

10. Alternative Uses

A variety of products can be produced from the kernels or from other parts of the sweet corn plant. Sweet corn is normally harvested roughly 3 weeks after pollination and at this stage all the plant parts are high in water content and are a potential source of subproducts. Alternative uses of subproducts can improve the agricultural waste management and profitability. Lau et al. [307] studied mineral and phytochemical compositions of sweet corn cobs to demonstrate that agricultural waste of sweet corn is a potential source of natural colorant (carotenoids), antioxidants (phenolics), and nutritional supplements (proteins and phytochemicals). Awosusi et al. [308] reported biocompositional and thermodecompositional analyses of agro-wastes of South African sweet and field corn for the potential utilization as biocommodities. The biomass might not be suitable for use in thermochemical process because of significant amounts of alkali metals in the samples and heavy metals in the ear husks. However, the waste samples had high volatile content and can be used in thermochemical process with improved yield per gram of feed. The high calorific value of cob samples and the low lignin-to-sugar ratio of the waste indicate that they are suitable as feedstocks in thermo-processing and bioprocessing.

10.1. Baby Corn

Baby corn can be produced with different types of maize, but sweet corn is one of the most common classes of maize used because of its quality and nutritional value [257,261,262]. Simons et al. [309] evaluated field corn, popcorn, white corn, and sweet corn genotypes for baby corn production and the genotype x environment interaction in Goias (Brazil) and found genotypic differences for most traits and genotype x environment interaction only for few traits. Stalks of baby corn and of the other specialty types of maize including sweet corn, can be used secondarily for forage. Chaudhary et al. [310] reported that different maize hybrids used for baby corn, sweet corn, forage, and field corn were potentially valuable sources, based on quality characteristics, for being used for silage in order to minimize the green fodder deficit in India.

10.2. Sprouts

Sprouting sweet corn kernels is a new process for increasing the nutritional value of resulting products, as they increase phytochemicals that are beneficial to health [281,311,312]. Xiang et al. [311] revealed a negative regulation in the genetic expression and the corresponding total phenolic content in the light treatment. Total phenolic and flavonoid content increased during germination and this was correlated with an increase in antioxidant activity. Therefore, the nutritional value of sweet corn improves through germination to the first complete leaf stage. Chalorcharoenying et al. [312] compared phytochemical compounds from seeds, sprouts, and seedlings of four small ear waxy corns, three waxy corns, three field corns, three sweet corns and three glutinous rice cultivars. Sprouts and seedlings increased carotenoid content, gamma amino butyric acid content, total phenolic content, and total anthocyanin content, and the highest increases in these phytochemicals were found in seedlings.

10.3. Extracts

Phytoglycogen and starch components are commonly extracted for industrial uses or cooking. Mishra et al. [313] assayed phytoglycogen and starch components in fresh kernels of 12 maize lines of field corn, sweet corn, and quality protein maize (QPM).

Sweet corn, field corn, and QPM differed significantly for water soluble and insoluble carbohydrate components and kernel weight. There were also significant differences within the endosperm types. Phytoglycogen is a naturally sweet corn polysaccharide. The highly-branched, dendrimeric structure of phytoglycogen increases softness and deformability of the particles and is water soluble. These properties are useful additives in personal care, nutrition, and biomedical formulations. Shamana et al. [314] described rheology measurements of aqueous dispersions of phytoglycogen, which behave as polymer glasses, suggesting the possibility of a hairy colloid particle geometry. The glucose dendrimer phytoglycogen is gaining interest for medical and biotechnology applications because of its unique structure and properties. Most applications rely on phytoglycogen extracted from *su1* sweet corn. Liu et al. [315] characterized the solubility, hydrodynamic diameter, water-binding properties, protein contaminant concentration, and cytotoxicity of phytoglycogens from different sweet corn genotypes. Phytoglycogen from some inbred lines (A619su1, Wesu7su1-NE) was cytotoxic while phytoglycogen from other inbred lines (A632su1-SW, Wesu7) was not, and the effect depended on the extraction method and time. Solubility was not associated with cytocompatibility, whereas protein contaminant concentration and water-binding properties were. These data demonstrate that maize phytoglycogen extracts are not uniformly cytocompatible. Rather, maize type, genotype, protein contaminants, and water-binding properties are determinants of phytoglycogen cytotoxicity.

Peng and Yao [316] evaluated sweet corn starch and cow cockle starch for their physical properties and branching pattern and compared them to normal corn starch, waxy corn starch, normal rice starch, and waxy rice starch. They concluded that small-granule starches have potential applications in industrial processes.

Chen et al. [317] evaluated four different varieties of corn fibers as the reinforcing phase to produce corn fiber polyethylene composites. The properties of corn fiber polyethylene composites were greatly influenced by the chemical composition of corn fiber and diverse sweet corn varieties resulted in different fiber characteristics.

10.4. Beverages

Several beverages are made from corn, though recent research about those using sweet corn are quite limited. Jusoh et al. [318] assessed the feasibility of sweet corn beverages as an alternative recovery drink for active people due to their high content of carbohydrate and protein levels. The product contains high carbohydrate and protein levels, and sensory and hedonic evaluation demonstrates that the product was well-liked and accepted by the majority of the consumers. Sweet corn extract can improve its function in probiotic drinks with the addition of lactic acid bacteria. Aini et al. [319] showed that increasing the concentration of the added potato culture increased the number of lactic acid bacteria, total acids, and viscosity, while pH, total dissolved solids, fat, and protein concentration decreased. Trikoomdun and Leenanon [320] tested the addition of corn milk samples prepared from sweet corn and water to produce corn milk yogurt and found that corn milk yogurt made from sweet corn and water at different ratios required different Lactobacillus strains.

10.5. Baking

Modern bakery trends include a variety of additives that increase commercial offerings, added value, and nutritional interests of their products. Lao et al. [321] used sweet corn residue to replace wheat flour in cakes and found that the content of dietary fiber, folate, vitamin E, and carotenoids significantly increased, and digestive characteristics improved simultaneously. Furthermore, sweet corn residue cake had similar sensory qualities to the control, while slowing digestibility and providing more micronutrients.

10.6. Forage

Sweet corn is harvested at fresh ear stage and the crop residue is often used as forage [67,240,310,322]. The potential value of sweet corn for feeding animals requires improving digestibility of the stalk. Zhou et al. [322] investigated the effects of inoculating *Saccharomyces cerevisiae* on nutritional composition and fermentation of sweet corn stalk. *S. cerevisiae* inoculum increased crude protein concentration but decreased silage quality. High-dose *S. cerevisiae* inoculum is not conducive to obtaining high-quality silage. *Saccharomyces cerevisiae* with *Lactobacillus plantarum* did not produce a net improvement in forage quality. Sweet corn stalks can be used for forage or silage alone or in combination with other crops. Wang et al. [323] evaluated the fermentation dynamics and bacterial diversity of mixed lucerne and sweet corn stalk silage and found that sweet corn silage enhanced the fermentation characteristics and improved structure of the bacterial community. Lopez et al. [324] investigated the effects of alkali and temperature during the alkaline pre-treatment of sweet corn co-products for the production of fermentable sugars with a lower chemical input. They found that increasing temperature reinforces the effects of soda on solubilization of hemicelluloses.

10.7. Bioenergy

As sweet corn stalk accumulates carbohydrates, fermentation of maize to produce ethanol can serve diverse uses, including renewable energy, which adds value to the residues and solves the problem of managing agricultural waste. Pan-in and Sukasem [325] used seeds, corncobs and cornhusks for anaerobic digestion with animal manure and reported diverse advantages and drawbacks of each combination and treatment for methanol production in Thailand. The cost-efficient degradation of fibers to fermentable sugars is a key factor in second generation bioethanol production, feed, food, and pulp and paper industries. Bautista et al. [326] used the stalk juice of a sweet corn hybrid for bioethanol production to maximize the value of the crop and solve the problem of agricultural residues and concluded that the process was successful. Ghio et al. [327] analyzed a complete set of carbohydrate-active enzymes encoded in *Paenibacillus sp.* A59 genome implicated in hemicellulose hydrolysis, contributing to understanding the mechanisms of bioconversion, focusing on the two main free secreted xylanases that can be used in industrial bioprocesses on lignocellulosic biomass.

11. Outlook

Sweet corn has spread from a crop mainly grown in temperate areas in the US and Canada to a crop grown worldwide. As the crop spread into new areas, farmers, processors, and consumers had new questions and confronted new problems. Researchers heard these questions and have attempted to address some of them, as evidenced by the over 300 papers cited here. The interest and markets for sweet corn will continue to grow and spread into tropical and subtropical regions. At same time, concerns about the impacts of pesticides and other farming practices on the environment and especially on biodiversity will continue to grow. These two forces will generate the need for even more research on production methods and sustainable practices. Some of the articles we have cited have also revealed that as an old crop like sweet corn moves into new places, local palates and culinary traditions will result in new uses for sweet corn, which will also be fertile ground for research. Along with new food uses they will be greater for researchers to improve the eating and nutritional quality, and food safety of the crop. We foresee that in five years there will be many more sweet corn publications than we have discussed from the last five years.

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