Horticultural Aspects for the Cultivated Production of Piquin Peppers (*Capsicum annuum* L. var. *glabriusculum*)—A Review

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Abstract. Piquin pepper [*Capsicum annuum* L. var. *glabriusculum* (Dunal) Heiser and Pickergill] is a semidomesticated pepper with high commercial value and wide applications as fresh or processed products. Piquin pepper plants have been difficult to domesticate and cultivate because of low seed germination, genetic and morphologic variability, insect and disease susceptibility, and limited environmental physiology information. Currently, seed sterility is no longer considered a limiting factor as hormonal, chemical, and thermal treatments have been developed to overcome seed dormancy. In vitro propagation (primarily by direct organogenesis) is still not reliable for seedling production. Cropping systems of piquin pepper plants include traditional methods such as agroforestry and full sunlight, and under protected horticulture conditions, mainly shade nets. Shade levels and water availability affect yield and vegetative growth. Piquin pepper plants can be grown under diverse geographic and edaphic conditions. Nutrition and fertilization studies are limited. Biotic stresses that can cause economic damage to piquin pepper plants include most that affect other pepper cultivars. Piquin pepper is also considered an important genetic resource as it reports resistance to some viral groups, which could be used for genetic improvement of other cultivated peppers. Current research needs involve the development of dependable plant materials (cultivated varieties) with reduced labor needs, particularly during the harvest period. In addition, research is needed to reduce the susceptibility of piquin pepper plants to other plant diseases. This review presents an analysis of the aspects related to the production of piquin peppers under cultivated conditions.

Piquin pepper plants [*Capsicum annuum* L. var. *glabriusculum* (Dunal) Heiser and Pickergill] are considered one of the predecessors of cultivated peppers (Eshbaugh, 1975; Medina-Martínez et al., 2010). As products, piquin peppers are highly appreciated for their aromatic profile, high pungency (average 60,000 Scoville units), crispy texture, and the popular belief that their consumption does not cause gastric irritation (Bosland et al., 1990). A limited supply along with high consumer demand causes the prices of piquin peppers to be much higher than those of other hot pepper cultivars (Contreras-Padilla and Yahia, 1998; Rodríguez-del-Bosque et al.,

2005; Villalón et al., 2013; Villalón-Mendoza et al., 2015).

Currently, most piquin peppers are collected from wild plants growing in their natural habitats (Medina-Martínez et al., 2010). A common harvesting method consists of removing branches and even entire plants, which compromises plant survival and has drastically reduced wild pepper populations (Coronado et al., 2013; Rodríguez-del-Bosque et al., 2005). Efforts have been made to regulate the collection activity (registry of wild specimens, raising social awareness, and legislation); however, overexploitation continues to occur (Miranda et al., 2007; Nabhan, 1990; Pedraza and Gómez, 2008) and needs to be addressed to maintain genetic variability and protect wild pepper plants in their natural ecosystems (Coronado et al., 2013; Pérez, 2014; Rodríguez-del-Bosque et al., 2004; Villalón-Mendoza et al., 2015).

The consumption of wild peppers varies by region. In northeastern Mexico, piquin peppers are preferred fresh in their immature (green) stage, while in northwestern and southern Mexico most wild peppers are consumed dry at their mature (red) stage (Bañuelos et al., 2008; Sandoval-Rangel, 2011; Villalón-Mendoza et al., 2016). Some peppers are consumed brined or pickled, or as ingredients of processed products foods and

of local cuisine (Bañuelos et al., 2008). Mature wild peppers are also sold into the U.S. markets (primarily to California and Arizona) as red dry condiments (Montes et al., 2006; Nabhan, 1990).

Piquin pepper plants are currently considered a semidomesticated crop, and further work is still needed to complete their domestication (Maiti et al., 1994; Murillo-Amador et al., 2015). The production of piquin peppers under cultivated conditions represents an opportunity for economic and social development of rural populations as it could aid in their integration into the formal economy by producing a highly demanded product (Coronado et al., 2013). The objective of this review is to provide an overview of research carried out into the domestication and cultivation of piquin peppers as a fully established horticultural crop.

Piquin Pepper Plants

Taxonomy. Piquin pepper plants (*Capsicum annuum* L. var. *glabriusculum*) belong to the Solanaceae family. The *Capsicum* genus originated in the western hemisphere (Bosland, 1994; Kraft et al., 2014) and encompasses more than 30 species and 400 cultivars (Chunab et al., 2011; Reddy et al., 2014). Five of these species (*C. annuum* L., *C. baccatum* L., *C. chinense* Jacq., *C. frutescens* L., and *C. pubescens* Ruiz and Pav.) include domesticated cultivars (González-Zamora et al., 2013; Kraft et al., 2014). Piquin pepper plants (*C. annuum* L.) have also been classified as *aviculare* (D'Arcy and Eshbaugh), *minus* (Figuerhut), *baccatum* (Terpó), and *minimum* (Heiser and Pickergill) (Bañuelos et al., 2008). Piquin peppers are also commonly known as “chiltepin” and “bird” peppers (Hernández-Verdugo et al., 2012).

Plant description. Although phenotypic characteristics are influenced by environmental conditions, average height of wild pepper plants is 55.8 cm but they can reach heights of up to 150 cm. Growth habits of piquin pepper plants vary considerably and range from herbaceous to climbing (Márquez-Quiroz et al., 2013; Miranda et al., 2010).

Piquin pepper flowers are small and are set on top of long (15–20 mm) and thin pedicels. One flower (occasionally two) arises per axil. The flowers have a white corolla comprising five white petals (15 mm diameter) (Fig. 1). The calyx (2–3 mm long) is green and thin. The ovary is obtusely conical (2.5 mm long). The style is 4 mm long. Anthers are purple to blue sitting on top of 1.5–2.5 mm stamen filaments (Bosland and Iglesias, 1992; Hernández-Verdugo et al., 2012).

Fruits of piquin peppers are compact, round, or oval shaped. Fruit size ranges from 0.87–1.68 cm length; 0.51–0.81 cm diameter; 0.2–0.55 g weight; and 0.45–0.82 mL volume. Piquin peppers are green during early development (unripe) turning to purple or orange at breaker stage, and then to red at full maturity (Salinas et al., 2010) (Fig. 2). Pepper color may change after harvest depending on

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maturity level, weather conditions, time of harvesting, and storage conditions (Gómez-Ladrón de Guevara et al., 1996; Mínguez-Mosquera et al., 1994).

Fully developed seeds are small (2.5–3 mm) with their radicle enclosed in a hard seed coating. Seeds are white to yellowish or tan, and may turn to brown when they lose viability (Chen and Lott, 1992; Eshbaugh, 1980; González-Cortés et al., 2015).

Weather requirements. The weather of natural habitats of piquin pepper plants is dry-hot to semidry temperate with summer rainfall (Medina, 2003). Although most wild pepper plants grow at altitudes of less than 1380 m (Miranda et al., 2007), some plants have been found at higher altitudes (greater than 2000 m) (Kraft et al., 2013). Piquin pepper plants grow favorably at average temperatures between 15 and 35 °C (Molina et al., 2010); average rainfall of 300–1000 mm; relative humidity between 75% and 100%; and a photoperiod of 14 h light and 10 h darkness. Piquin pepper plants are easily killed by exposure to temperature conditions in the –1 to 0 °C range for a couple of hours (Almanza, 1998; Miranda et al., 2007).

Natural Populations

Variation between populations. Results of random amplification of polymorphic DNA (RAPD), isozyme, and comparative studies

have established that piquin peppers present high genetic variability (among and within populations) with high phenotypic plasticity (Castañón-Nájera et al., 2014). Differences in plant characteristics, fruit and leaf morphology, seed germination, and pathogen susceptibility make it difficult to develop consistent base protocols for germination, fruit production, and resistance to viral diseases (González-Jara et al., 2011). Environmental conditions may intensify these differences as rainfall and temperatures affect morphological response, including plant and fruit size and number of seeds per fruit (Castañón-Nájera et al., 2014; Murillo-Amador et al., 2015).

Plant dispersion. Seeds of mature wild peppers are naturally dispersed by a number of bird species including great kiskadee (*Pitangus sulphuratus* Linnaeus), mockingbirds (*Mimus polyglottos* Linnaeus), and curve-billed thrasher (*Toxostoma curvirostre* Swainson), among others (Almanza, 1998; Tewksbury et al., 1999; Tewksbury and Nabhan, 2001). Once consumed, seeds pass through the bird's digestive tract and are dispersed through their depositions (commonly in partially shaded conditions in the understory of trees) (Almanza, 1998; Araiza et al., 2011; Rueda-Puente et al., 2010). Capsaicinoids consistently cause digestive retention in birds. Capsaicin can be viewed as the chemical intermediary of the trade-off between dispersal distances, which are positively correlated with retention time (Tewksbury et al., 2008).

Nurse plants. Nurse plants facilitate growth and development of other plant species under their canopy as they offer favorable microclimate conditions (reduced soil temperature with increased soil humidity and organic matter) for seed germination, early growth, and plant development (Bañuelos et al., 2008; Miranda et al., 2007; Ren et al., 2008). Piquin pepper plants, in their natural habitats, may associate with nurse plants including velvet mesquite (*Prosopis velutina* Woot) or feather bush or fern-of-the-desert (*Lysiloma watsonii* Rose).

Cultivation of Piquin Pepper Plants

Domestication process

Fruit collection from wild specimens and backyard production of piquin peppers has

occurred for many years in regions where wild peppers exist naturally. This predomestication management had not caused clear phenotypic evidence of domestication but could have had implications for the richness of population's genetics (Bañuelos et al., 2008; Casas et al., 2007; Perramond, 2005; Teran et al., 1994). Monoculture plots of piquin pepper plants have been successfully established (Araiza et al., 2011; Villalón et al., 2013), but most cultivation occurs in small areas (less than one hectare) and in small greenhouses (Márquez-Quiroz et al., 2013; Medina-Martínez et al., 2010). Piquin peppers in monoculture plots show no obvious phenotypic differences in fruit size, shape, hanging, color, pungency, or rate of synchronized germination when compared with their wild counterparts (Araiza et al., 2011; González-Jara et al., 2011; Villalón et al., 2013).

Total domestication of piquin pepper plants has not been fully achieved primarily because of low and erratic seed germination, disease susceptibility, and limited reliable information on the crop. In their natural habitat, wild pepper plants reproduce in the rainy season, and they can live for 5–8 years (Fraile et al., 2017). By comparison, when cultivated under full sunlight, piquin pepper plants are grown as annual crops using standard horticultural practices (Rodríguez-del-Bosque et al., 2004).

Phenology

Phenological development of piquin pepper plants is more protracted than in other pepper cultivars, and depends on ecotype and environmental conditions. Under cultivated conditions, piquin pepper plants require 7–28 d for seed germination, 60–90 d for seedling development, 60–70 d for vegetative development until the onset of flowering, and 30 d for the first commercial fruits (Almanza, 1998; Jiménez-Leyva et al., 2017; Valiente-Banuet and Gutiérrez-Ochoa, 2016).

Cropping systems

Cropping systems of piquin pepper vary from traditional (agroforestry and intercropped production) to production in horticultural systems under full sunlight or using shade nets. In agroforestry, piquin pepper plants are placed at 10–15 m from the edge of natural forest ecosystems and plant canopies protect against pests (e.g., whitefly and aphids) (Rodríguez-del-Bosque et al., 2004). Reduction of weed competition and keeping adequate soil water levels are important as piquin pepper plants can withstand reduced water availability but are nonproductive (Mena, 2004). Intercropped production refers to the establishment of piquin pepper plants in association with perennial crops. In this type of system, pepper plants are established in rows near the main crop, and production and cultural practices are performed for both crops. As intensive horticulture production systems, piquin peppers are produced as monoculture crops under full sunlight or shade nets at different levels of light

Fig. 1. Image of piquin pepper plant, flowers, and fruits.

Fig. 2. Color change of piquin peppers during fruit maturation.

interception (Rodríguez-del-Bosque et al., 2004). Yield is the highest under partially shaded conditions followed by full sunlight, and then under agroforestry and intercropped production systems, which are comparable among themselves (Rodríguez del Bosque, 2003; Valiente-Banuet and Gutiérrez-Ochoa, 2016).

Sexual plant propagation

Commercial cultivation of piquin peppers has been hampered by reduced seed germination (less than 5% in some ecotypes) (Almanza, 1998). Seed dormancy may be related to its hard seed coating (Eshbaugh, 1980; González-Cortés et al., 2015), the presence of inhibitors in the pericarp or seed, or high capsaicin levels (Barchenger and Bosland, 2016; Prado-Urbina et al., 2015). In addition, embryos of mature seeds can be rudimentary, physiologically immature, or not fully developed; and need at least two months after harvest for full maturation. Furthermore, seed viability is reduced to less than 3% at the end of 1 year (Sandoval-Rangel, 2011). Nevertheless, natural seed sterility is no longer considered a limiting factor for commercial cultivation of piquin pepper plants as a number of protocols have been developed to overcome it such as manipulation of light and temperature, chemical, and hormonal treatments (González-Cortés et al., 2015).

Light and temperature fluctuations. Germination of piquin pepper seeds is affected by light and temperature fluctuations. Seed germination was less than 10% when seeds were exposed to dark conditions, and 30% with a constant temperature of 25 °C and 12 h light and 12 h dark photoperiod for two months. However, seed germination increased to 60% by exposure of seeds to fluctuating temperatures (25 to 34 °C) at the same photoperiodic conditions (Hernández-Verdugo et al., 2001).

Chemical treatments. Seed treatments that have increased germination rate include chemical treatments (Araiza et al., 2011). Monosodium glutamate and salicylic acid increased seed germination and stimulated vegetative growth (Sandoval-Rangel, 2011). The use of amino acids in combination with fulvic acids has also been reported to increase germination (García et al., 2010). Other chemicals with enhancing effects on germination include KNO_3 and H_2O_2 (Cano-Vázquez et al., 2015).

Hormonal treatments. Hormonal treatments, including gibberellins, auxins, and cytokines, have also improved the germination of wild peppers (González-Cortés et al., 2015). Gibberellic acid (GA) has been successfully used to break dormancy without changing other environmental factors (light or temperature) (Hernández, 2004). GA application at a rate of 5 g·L⁻¹ during 24 h at ambient temperature increased seed germination up to 60% to 80%, when compared with untreated seeds (Araiza et al., 2011; Medina-Martínez et al., 2010). The enhancing effect of GA on germination was consistent

with wild pepper seeds across locations in Mexico and the United States. The increase in seed germination rate was genotype dependent (Cano-Vázquez et al., 2015; Ramírez-Meráz et al., 2003; Hernández-Verdugo et al., 2006).

Vegetative plant propagation

Although seed sterility is no longer considered a limiting factor for the cultivation of piquin pepper plants, some vegetative propagation techniques have been evaluated aiming to obtain wild pepper plants without genetic segregation, or at reducing the time needed to obtain piquin pepper plants (González-Cortés et al., 2015).

In vitro tissue culture. *Capsicum* is considered a recalcitrant genus for in vitro cell, tissue, and organ differentiation, and for plant regeneration (Kothari et al., 2010). However, the use of in vitro techniques remains a possibility for the propagation of piquin pepper plants (Cardenas et al., 1997) and research on this field is promising; as when successful, *in vitro* propagation has yielded true to type plants and has shown improved horticultural performance in relation to their seed-derived counterparts (reduced time for seedling growth and enhanced fruit production) (Amzad et al., 2003; Valadez-Bustos et al., 2009).

Several protocols have been developed for in vitro culture of pepper plants, but they still have not been proven efficient, reliable, or broad spectrum for all *Capsicum* plants. Results are affected by genotype variability that causes changes in the responses to tissue culture. Some difficulties are related to different plant response based on explant source, regeneration medium, and the formation of abnormal organs (Steinitz et al., 2003).

In vitro regeneration of piquin pepper plants has been achieved primarily by direct organogenesis methods. Regeneration efficiencies vary depending on genotype, culture media, and source of explant (hypocotyls and seed embryos are considered better explant sources than others, including cotyledons). The number of adventitious shoots obtained from in vitro explants of piquin pepper plants was more variable than those for other peppers, including jalapeño, serrano, and habanero (Valadez-Bustos et al., 2009).

Most propagation studies using in vitro technologies have focused on regeneration protocols primarily. Horticultural performance (fruit or seed production comparing between seed-derived and regenerated plants) has not been fully addressed. This information is necessary to determine the potential commercial applications of this technology (Amzad et al., 2003).

Rooting of branch cuttings. The success of asexual reproduction of wild peppers by rooting branch cuttings depends on the interaction of endogenous and exogenous factors. Endogenous factors that affect regeneration capacity of pepper branches include plant and shoot age, as well as size and number of buds per shoot (Molina et al., 2010; Murashige, 1974). The best

rooting results (40% success rate) involved the use of two-node cuttings, 2–4 mm in diameter, treated with a 0.067% solution of 1-naphthaleneacetamide; 0.033% 2-methyl-1-naphthalene acetamide, 1-H-indole butyric acid; 4% thiram [Tetramethyl thiuram disulfide (or Rootone®)] and rooted in a horticultural sphagnum moss: vermiculite: perlite plus lime substrate (1:1:1; Promix BX®), supplemented with superphosphate, calcium nitrate, and microelements (Premier Brands, New Rochelle, NY) (Sultanbawa and Phatak, 1991).

Air layering. Air layering has also been successful for the propagation of pepper plants with desirable characteristics without genetic segregation. Rooting success rate was improved in more than 50% when a solution containing 3000 ppm of indole acetic acid was added to the peatmoss substrate in comparison with applied directly to the cut surface (Mohamed et al., 2014).

Plant nutrition

Fertilization requirements. Fertilization studies on piquin peppers are limited. Current recommendations for NE Mexico indicate that in intercropped ecotypes, base fertilization should be ≈ 5 g P_2O_5 per plant and 2.5 g per plant of N per month. This recommendation should be paired with adequate irrigation practices to improve fertilizer uptake (Rodríguez-del-Bosque et al., 2004).

Mycorrhizae. Mycorrhizal inoculation of piquin pepper plants using *Glomus intraradices* (N.C. Schenck and G.S. Sm.) and *Glomus fasciculatum* (Thaxter sensu Gerd.) increased plant height and width, and yield in 61%, 56%, and 135%, respectively, in relation to the uninoculated control plants (Rodríguez-del-Bosque, 2003). Depending on the phenological stage of the plants and phosphorus availability, the levels of native arbuscular mycorrhizal propagules modified the functional colonization patterns of roots and consequently the contents of N, P, and other macro and micronutrients in shoots (Jiménez-Leyva et al., 2017).

Organic amendments. Vegetative and reproductive development of piquin peppers responded to organic amendments (Márquez-Quiroz et al., 2013). Vermicompost application during seedling production resulted in increased plant growth, weight, leaf, and fruit production when compared with untreated plants (Brown et al., 1999). Vermicompost also enhanced plant height, weight, and number of leaves of piquin pepper when compared with earthworm (*Pontoscolex corthurrus* Muller) treatments or rhizobacteria (*Aspergillus brasiliensis* Varga, Frisvad and Samson) (Huerta et al., 2010).

Vermicompost in combination with a mixture of sand and compost, or simply sand, can be considered an alternative for organic piquin pepper production under greenhouse conditions. However, the yields obtained using vermicompost were still lower than those from plants cultivated with sand and inorganic nutrient solution (containing NO_3^- , NH_4^+ , H_2PO_4^- , K^+ , Ca^+ , Mg^+ , SO_4^+ , HCO_3^- ,

Na⁺, and Cl⁻ at different concentrations) (Márquez-Quiroz et al., 2013).

Branch pruning. Pruning of piquin pepper branches increased sprouting, flowering, and fruiting dynamics of wild pepper plants. If pruning is performed, plants should not be cut to more than 50% of the total plant height (Morales, 1986).

Environmental Conditions

Soil types and salinity. Soils recommended for the cultivation of piquin peppers should be deep and well drained. In addition, crop rotation with Gramineae or Leguminosae can help to reduce the risk of plant diseases and soil degradation problems (Mena, 2004).

Screening for salinity resistance in wild pepper ecotypes from different Mexican states indicated a greater tolerance of wild peppers to high NaCl concentrations (from 0 to 300 mM) than for other commercial peppers (e.g., Poblano). To tolerate high NaCl exposure, wild pepper plants reduced and maintained low transpiration rates, maintained chlorophyll production, and accumulated sodium ions in leaves. By comparison, poblano pepper plants lacked these tolerance mechanisms making them more susceptible to high salinity conditions (Medina, 2009).

Light intensity and irrigation. As previously mentioned, cultivated production of piquin peppers can be carried out at full sunlight or under shade nets at different levels of light interception. At full sunlight, piquin pepper plants are considered annual crops as frost, disease, and pests limit the productive cycle (Rodríguez-del-Bosque, 2003). Piquin pepper crops appear to be more successful if established under shade nets at low levels of light interception (35% shade). As light interception increased from full sunlight to 80% shade, vegetative growth was favored by increasing branching and leaf size to maximize light interception (Dudley, 2004; Valiente-Banuet and Gutiérrez-Ochoa, 2016). Shaded horticultural production seems to replicate the natural habitat of piquin plants in the understory of trees (Rodríguez-del-Bosque, 2003; Rodríguez-del-Bosque et al., 2005).

Fruit yield was increased at moderate shade (35%) and reduced at higher shade levels (>50%). An intermediate light intensity increased stem diameter, quantity of fruits, seeds per fruit, and number of seeds per plant in comparison with full sunlight and low irradiance conditions (Hernández-Verdugo et al., 2015). Shade nets can also reduce other fruit physiological disorders (including sunscald) and damage by pests, birds, winds, and high temperatures (Rodríguez-del-Bosque et al., 2004).

The effect of shade nets on plant size and yield is also related to irrigation frequency. Plant height and lateral growth were higher under shaded conditions and more frequent irrigation. The highest yields were obtained at 35% shade levels and daily irrigation. The yield was reduced when plants were exposed

to high levels of shade and to reduced irrigation frequency (Valiente-Banuet and Gutiérrez-Ochoa, 2016).

Biotic stresses of piquin pepper. Insect species that can cause economic damage to piquin peppers include most that affect other pepper crops. The major arthropod pest is pepper weevil (*Anthonomus eugenii* Cano). Adult weevils feed and oviposit in buds, flowers, and fruits. Larvae develop and feed inside those organs reducing crop yields (Toapanta et al., 2005). Spider mites (*Tetranychus urticae* Koch) are polyphages acari that feed on cells containing chloroplasts and cause perforation and damage to leaves, reduce leaf area, and deform young shoots (Herrmann et al., 2012; Mena, 2004; Rodríguez-Leyva et al., 2007). May beetles (*Phyllophaga* spp. and *Anomala* spp.) feed on roots and decaying plants. Larvae of the American serpentine leafminer fly [*Liriomyza trifolii* (Burgess)] cause damage by mining leaves, which result in the destruction of leaf mesophyll and cause severe defoliation in pepper plants. Whiteflies [(*Bemisia tabaci* (Gennadius) Takahashi and *B. argentifolii* Bellows and Perring)] cause direct damage by feeding on the phloem and indirectly by transmitting more than 100 plant viruses. Aphid species [(*Myzus persicae* (Sulzer) and *Aphis gossypii* (Glover)] are also considered effective transmitters of viral diseases that cause leaf and shoot curling affecting flowers and fruits (Caro et al., 2014; Garza, 2001; Morón, 1986; Palumbo et al., 2001; Sandoval-Rangel, 2011).

Fungal and viral plant diseases can have a strong impact on piquin pepper crops. The most important fungal diseases include *Fusarium* spp. that causes stem rot and plant wilting (Agrios, 2005; Sundaramoorthy et al., 2012); *Rhizoctonia* spp. that causes plant rot (Sid et al., 2003); and *Phytophthora capsici*, which causes root and crown rot, forms black lesions on stems, and infects leaves causing circular lesions grayish-brown (Ristaino and Johnston, 1999). Viral infections in piquin pepper include Chiltepin yellow mosaic virus, which induce severe symptoms and cause a significant reduction in plant growth; *Pepper golden mosaic virus* that causes leaf wrinkles and reduced growth plant. *Pepper huasteco yellow vein virus* has a two-stranded genome (DNA-A and DNA-B) from single-stranded DNA and causes leaf deformation (Pagán et al., 2010; Rentería-Canett et al., 2011; Rodelo-Urrego et al., 2015). Human management of wild piquin pepper population has resulted in an increase of virus infection (Fraile et al., 2017).

Wild pepper is considered an important genetic resource, as it has been reported with resistance to several viral groups including *Tobamovirus*, *Potyviridae*, *Geminiviridae*, and Bell pepper *endornavirus* (BPEV). Knowledge of pests and diseases helps in the development of strategies to anticipate, control, and understand the ecological role of population dynamics and genetic diversity (Okada et al., 2011; Pagán et al., 2010; Rodelo-Urrego et al., 2015).

Limitations for the Cultivation of Piquin Peppers

Currently, the commercial cultivation of piquin pepper plants still faces challenges related to reduced availability of registered cultivars and high variability of wild populations. To this date, a single commercial cultivar has been registered: the Númex Bailey Piquin (Bosland and Iglesias, 1992). In addition, high variability of wild piquin pepper populations limits the applicability of the studies to the local conditions and ecotypes. More cultivars, along with their corresponding environmental physiology information, are needed to adjust to conditions in the different production areas. In particular, studies are needed regarding mineral nutrition, optimal planting density, and plot size for the different ecotypes.

High manual labor requirements, particularly, during the harvest period, also limits the cultivation of piquin peppers. The commercial cultivar Númex Bailey Piquin was developed with the aim to reduce costs by mechanical harvesting as the peppers can be shaken from the plant (Bosland and Iglesias, 1992). However, the development of additional cultivars with reduced labor requirements is also needed.

In addition, further work is needed to reduce disease susceptibility of piquin pepper plants to several plant viruses (Poulicard et al., 2016) and to address postharvest processing and quality standards for commercialization.

Conclusion

Piquin peppers are highly valued horticultural products with a wide array of applications for direct consumption and as a source of compounds or genes with economic importance. The cultivated production of piquin peppers has not been entirely possible due to a series of difficulties that range from low seed germination, morphologic and genetic variability, insect and disease susceptibility, and limited environmental physiology information. This article presents a comprehensive review of the main aspects toward the achievement of cultivated production of piquin peppers.

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