Dissertation for the degree of Doctor of Philosophy

Morphological Diversity Analysis of *Capsicum annuum* Using an Image-Based Method for Crop Improvement

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Abstract

Chili is a valuable crop with many uses, including as a source of flavour and nutrition. To develop new varieties with desirable traits, it is important to analyze the genetic diversity of chili germplasm. Traditional methods of analysis can be time-consuming and labour-intensive. Therefore, this study aimed to improve crop breeding and production by using image-based methods to analyse the morphological diversity of chili germplasm. The study analysed 188 accessions of *Capsicum annuum* from 36 countries, and the geographic origin data for each accession was obtained from the National Seed Resources in Korea. The study focused on three leaf traits and their correlation with stem angle, length, and thickness, as well as fruit area, length, width, and thickness. Additionally, the correlation between flower area and fruit characteristics were also studied. The results showed significant variability in leaf area, leaf length, and leaf width among the two populations (K=2), with CV values of 0.38, 0.18, and 0.22, respectively. The average leaf area was 5,317mm^2, while the average leaf length ranged from 100 to 166mm and the average leaf width ranged from 45 to 75mm. The average stem length ranged from 180 to 301mm, and the thickness ranged from 15 to 26mm. The study also found that the average fruit area was 169.76mm^2 with a CV value of 0.79. The average fruit length ranged from 21 to 35mm, while the average fruit width ranged from 5.4 to 9mm. Furthermore, the study identified significant diversity in qualitative characteristics such as flower area. The results indicated that leaf area, width, and length are strongly correlated with flowering and fruit production in chili genotypes. The principal component analysis (PCA) showed a variation of 43.09% and 18.1% among leaf, stem, fruit and flower traits. There was a strong correlation among leaf, fruit and flower traits as compared to stem traits. Additionally, three traits, including flower area, fruit thickness, and fruit area, were identified as crucial for describing a breed. The study's results can contribute to the advancement of breeding programs, enabling the development of improved chili varieties that meet the requirements of consumers and producers. Utilizing advanced genotyping and phenotyping technologies, along with a more comprehensive understanding of the underlying genetic and

physiological processes that govern these characteristics, breeders can develop crops that better fulfil these expectations. These findings may aid in the development of more resilient and high-yielding chili varieties.

General introduction

Capsicum (*Capsicum annuum* L.) is a crop in the *Solanaceae* family, Capsicum genus, native to South America, is distributed between the southern United States and northern Argentina, and cultivated worldwide. The genus has a high concentration of genetic variation in the headwaters of the Amazon River in the eastern Andes, along the border between Peru and Bolivia, or Paraguay and Brazil (Eshbaugh, 2012). There are approximately 25-30 wild species of Capsicum, with *C. baccatum, C. chinense* Jacq.*, C. frutescens, C. pubescens, and C. annuum* dominating the five cultivated species, which are grown as perennials in the tropics and annuals in temperate regions (Bebeli *et al.,* 2008; Ornelas-Ramírez *et al.,* 2021).

C. annuum L, is native to the South American continent and is currently the most commercially and most widely cultivated species of chili not only in South Korea but in the world (Lee *et al.,* 2013; Singh *et al.,* 2015; Ornelas-Ramírez *et al.,* 2021). *C. chinense Jacq.* is the most popular cultivar in the world, including some of the hottest chilies such as Mexican avanero, scotch bonnet, and rocotillo. This species originated in the Amazon and quickly became common throughout Central and South America, the Caribbean, and the tropics. *C. frutescens* L, has not become as widespread as the others, but it is the chili from which the hot sauce Tabasco is made. Thought to be native to Brazil, this species also includes the famous Malagueta chili variety. *C. baccatum* L. Ruiz is commonly known as 'aji' and is included in the South American varieties. *C. pubescens* L. is the least common of the five cultivated species and the only one without a wild form, and includes Mexican manzano chilies and Peruvian rocoto (Parvinder *et al.,* 2015; Ornelas-Ramírez *et al.,* 2021). In a rapidly changing society, people change to keep pace with the changes, and farmers and consumers increasingly want crops with various conditions (Zhao *et al.,* 2022). Therefore, crop breeding is identifying the preferences of farmers and consumers and creating new varieties to meet various needs (Kim *et al.,* 2019; Crossa 2022; Zhao *et al.,* 2022).

Chili is severely affected by environmental and genetic constraints, which are reflected in its yield and quality. The spicy flavor and nutritional content of chili is a challenging trait to breed because its flavor and nutrient content are highly variable depending on the growing environment, fruit set location, and harvest time (Aquino *et al.,* 2022). Therefore, it poses many challenges for crop variety renewal or new variety development (Atlin *et al.,* 2017). Advances in DNA sequencing have improved the speed and efficiency of genotyping costs, but there are limitations in understanding how the yield and growth of these varieties are affected by the environment compared to other varieties (White *et al.,* 2012). Even genomic analysis techniques such as marker-assisted recurrent selection (MARS) and genomic selection require phenotypic information to provide relevant information (Heslot *et al.,* 2015).

In response, scientists are adopting new breeding techniques, including new genomic tools and technologies (Araus & Cairns, 2014; Ahmar *et al.,* 2020). Phenotyping is an integral part of understanding the effects of genotype, environment, and field management on crop health and function, and is an experimental method that needs to be addressed to rapidly meet the demands of the changing landscape (Tariq *et al.,* 2020). Phenotyping is a method of observing crops through imaging, which allows for fast, high-volume observation and diagnosis without damaging the crop, and is a method of observing genetically diverse morphological features of crops using imaging. Phenotypic methods are easy and quick to obtain and can be used to estimate chili traits such as yield, plant height, leaf area index, canopy temperature, nitrogen uptake, etc. and can be useful for collecting objective data over time to understand the overall history of the chili, which can be beneficial to breeders, growers, and consumers (Walter *et al.,* 2015; Dreccer *et al.,* 2019; Yang *et al.,* 2020).

Therefore, in this study, we used CMOS sensors to acquire images of each part (leaf, stem, flower, and fruit) of 188 chili plants collected from the National Seed Resource, and then calibrated them to quantify various types of data (area, size, and thickness) to evaluate the correlation among them.

Chapter I. General literature review

1. Introduction

The Food and Agriculture Organization (FAO) of the United Nations (UN) has reported that crop production will need to increase by about 60% from current levels by 2050 due to global population growth (FAO, F, 2018; World Health Organization, 2020). However, in recent years, global warming and climate change have resulted in warming events and severe yield losses in crops, increasing food security challenges globally (Hubert *et al.,* 2010; Song *et al.,* 2022). To overcome these challenges, new crop breeding and cultivation technologies are required to increase food production in the future, and crop breeding programs and cultivation technologies have been steadily developed to increase crop productivity and improve crop quality (Lee *et al.,* 2021; Song *et al.,* 2022).

With the rapid development of second and third generation DNA sequencing methods called next generation sequencing (NGS) in the last decade, gene functions are being analyzed using various analysis groups such as core groups, inbred groups, and trait analysis using markers (Go *et al.,* 2013; Jung *et al.,* 2018). Genetic information data are being produced at an exponential rate, and the analysis and processing of these data are already being used globally to predict gene functions through correlation analysis with crop phenotypes, but there are difficulties as a bottleneck in phenotypic research (Go *et al.,* 2013; Jung *et al.,* 2018).

Recently, the field of phenomics has emerged to analyze the phenotypes of these crops quickly and in large numbers. Phenomics is a combination of phenotype and omics. Phenotype, in a narrow sense, refers to any trait that can be observed by the eye, such as the shape or color of an individual. Whereas, phenomics is a stem of biology that phylogenetically interprets the entire phenotype, that is, the physical, morphological, and physiological characteristics of an organism, such as tissues and organs, that are determined by genetic and environmental factors, such as the concentration of proteins in glucose cells in the blood (Houle *et al.,* 2010; Yang *et al.,* 2013; Lee *et al.,* 2021).

Plant phenotype refers to the morphology or physically observable model of a plant (Lee *et al.,* 2011). To measure plant phenotype, images of plants are acquired using imaging sensors such as visible light, near-infrared, fluorescence imaging, hyperspectral, infrared thermal imaging, X-ray CT, and MRI, and analyzed to quantify plant characteristics such as plant shape, leaf width, color, and aboveground and belowground parts (Lee *et al.,* 2011). The parameters of plant phenotype include leaf color, leaf width, ultrastructure, root morphology, biomass, leaf characteristics, fruit characteristics, yield-related traits, photosynthetic efficiency, and biotic and abiotic stress responses (Li *et al.,* 2014).

These plant phenotypes require effective and reliable phenotypic data to accurately and rapidly develop high-throughput methods for plant breeding (Omari *et al.,* 2020). However, the evaluation of phenotypic traits for disease resistance or stress in various breeding programs is time-consuming and requires large populations and repeated measurements, and it also relies heavily on visual scoring, which can cause bias among researchers (Fiorani, F & Schurr, U., 2013, p. 13; Li *et al.,* 2014). To compensate for these problems, non-destructive and high-throughput screening methods can be used to automate and objectively measure a large number of accessions and repeated measurements to obtain reliable plant phenotypic data and maximize efficiency by minimizing the time and effort required to perform targeted experiments (Chang *et al.,* 2011; Li *et al.,* 2014; Rutkoski *et al.,* 2016).

2. High throughput phenotyping

2.1. Conventional method

The study of plants has traditionally relied on the human senses. Visually, the size, color, and shape of plants were used to analyze their growth status (Li *et al.,* 2021). When analyzing growth status visually, ordinal, continuous, and binary scales are used to analyze quantitative characteristics. Binary scales can only make two types of diagnoses: yes/no or absent/present (Riley *et al.,* 1996). Quantitative traits are recorded by measuring, counting, or weighing and using a continuous scale. Some characteristics can be expressed as degrees and are recorded on a scale (1 to 9). Qualitative characteristics, on the other hand, are numbered to define the characteristic by name, color, and shape (Summerfield *et al.,* 1996).

Also, the sense of smell was used to distinguish pests and senescence by the aroma of plants (Riley *et al.,* 1996; Summerfield *et al.,* 1996). When analyzing growth status with the sense of smell, qualitative data may include nutritional and flavor characteristics such as high oil content in oilseed crops, high oleic acid levels in vegetable oils, high protein content in legumes, and odor, color, and flavor in fruits and vegetables. And taste could be used to determine the flavor and usefulness of a plant (Lane *et al.,* 2021; Riley *et al.,* 1996; Summerfield *et al.,* 1996).

However, sensory methods have their limitations. For these measures to be used in agriculture, agro-morphological traits must be universal. Otherwise, inconsistent characterization can lead to misleading breeding studies (Lane *et al.,* 2021). When measuring a plant's canopy, accurate measurement becomes difficult beyond human height. When it comes to seed color, it is difficult to objectively distinguish between white and yellow intermediate colors, and there are also limitations in terms of determining and analyzing stress levels or photosynthetic efflux without damaging the plant (Carvalho *et al.,* 2021).

In this way, different researchers may be context-dependent and subjective when distinguishing and measuring plant traits, making it difficult to obtain objective figures and taking a lot of labor and time. Therefore, for the objective measurement of plants, efficient phenotyping from the plant breeder's point of view should consider two perspectives (Bioversity International, 2007). First, the availability of appropriate tools to measure the traits of interest should be considered. Plant breeding requires simple, fast, and high-throughput (HTP) methods that are well adapted to key agronomic, physiological, and technological traits (Jaramillo *et al.,* 2002). Secondly, phenotypic planning should be considered. For efficient use of the acquired data, it should be suitable for selection purposes and comparative experiments (Qiu *et al.,* 2018). Therefore, there is currently a shift from human senses to ICT-based sensing technologies for plant growth, growth environment, and data analysis (Kumar *et al.,* 2015).

2.2. Image-based research

2.2.1. Red, green, and blue (RGB) image

Visual images are images in the visible light region (400-700 nm) that are visible to the human eye and represent the red (R), green (G), and blue (B) color spaces using a charge coupled device (CCD) or complementary metal oxide semiconductor (CMOS) sensor (Jo *et al.,* 2019). The basic unit of measurement for an image is the R, G, and B values of a pixel. In addition, there are various color spaces such as HVS, which consists of hue, saturation, and value, and CMYK, which consists of cyan, magenta, yellow, and black, which can quantitatively express information about colors for analysis purposes (Noh *et al.,* 2018; Jo *et al.,* 2019). In addition, CCD and CMOS sensors are generally the most common imaging sensors and are used to analyze visible characteristics such as morphology, biomass, and architecture of plants due to their low cost, ease of use, and highest resolution (Golzarian *et al.,* 2011; Noh *et al.,* 2018). Since plants can absorb a lot of light in the visible region from 400 nm to 680 nm, CCD and CMOS sensors can be used to obtain information about plant growth and development (Kim *et al.,* 2014). Mohammadi *et al.* (2021) applied a pixel-by-pixel calculation of leaf length, width, and circumference, the most important growth indicators of chili leave, in RGB images. Ghosal *et al.* (2018) trained over 25,000 images to consistently and quickly provide accurate foliar stress severity for stresses such as bacteria, fungi, nutrient deficiencies, and chemical damage.

2.2.2. Near infrared image

The near-infrared is the shortest wavelength of the infrared, close to the visible light region, and falls in the region of 700-2500 nm (Lee *et al.,* 2011). Moving into the near-infrared, plants reflect most of the light, but their near-infrared metrics change depending on the water content within the plant (Yang *et al.,* 2013). Because of this fact, many studies have used NIR imagery to measure the overall health of plants as a function of water stress, which can be calculated as the normalized difference vegetation index (NDVI) (Rahaman *et al.,* 2015). Here, NDVI is calculated as shown in Equation 1.

$$NDVI=(NIR-R)/(NIR+R) \quad (1)$$

Since the index is calculated through a normalization procedure, if the NDVI value ranges from 0 to 1, even areas with fewer plants may be sensitive to green. Pandey *et al.* (2017) used NIR imagery to measure the moisture content of corn, and Hwang *et al.* (2022) used NIR imagery to study the variation of weed density in soybean packages. Therefore, NIR imagery can be used as an indicator of water stress in plants by measuring the water status in the plant body.

2.2.3. Fluorescence Image

Plants photosynthesize by receiving light from the external environment, and photosynthetic activity can be reduced by various environmental stresses. Chlorophyll fluorescence measurements can be used to obtain a measure of plant stress by measuring reduced photosynthesis levels (Chaerle *et al.,* 2007). Chlorophyll fluorescence is the short-lived light that plants typically emit when they transition to the ground electronic state. It also emits lower energy in the excited electronic state when the plant has absorbed energy utilized for photosynthesis.

Many substances become fluorescent when illuminated with light that contains a high percentage of ultraviolet light. When chlorophyll, which is involved in photosynthesis in plants, is irradiated with blue light or chemical light, a portion of the light absorbed by the chlorophyll is re-emitted, resulting in a re-emission rate of the absorbed light (Li *et al.,* 2014). Comparing the ratio of irradiated to re-emitted light, the ratio of re-emitted light is more variable and depends on the plant's ability to metabolize the harvested light (Maxwell & Johnson, 2000). This re-emitted light is fluorescent and is a good indicator of the plant's ability to absorb chemical light (Mishra *et al.,* 2016). By measuring the light emitted and storing it as an image, it is possible to determine the optimal concentration of herbicides to be used, or to select disaster-resistant individuals by measuring their photosynthetic capacity under stress treatments (Jang, 2000; Kim & Ok, 2015). These fluorescence imaging techniques provide a powerful diagnostic tool to address the problem of heterogeneity in leaf photosynthetic performance and are used in many areas of plant physiology (Baker, 2008).

2.2.4. Hyper-spectral image

Hyper-Spectral Imaging (HSI) is a technology that adds spectral technology to spatial information and organizes two-dimensional image information such as RGB image information according to the spectrum band of electromagnetic waves in the form of a hyper-spectral cube to derive the state, composition, feature, and transformation of the object, enabling analysis in various ways (Lee *et al.,* 2019).

Hyperspectral imagery has more than 100 spectral bands and can reveal the integrated characteristics of plants because it has enough spectra to determine the nature of plants (Noh *et al.,* 2018; Lee *et al.,* 2019). In addition, hyperspectral data contains frequency bands in the infrared region that are not perceivable in visible light from 400 to 2,500 nm, and this characteristic makes it possible to understand vegetation indicators using hyperspectral images. For example, it is a method for obtaining quantitative basic data such as photosynthetic absorption activity, pigment content, adaptability to stress environment, chlorophyll index, and resistance diagnosis (Ahn *et al.,* 2012; Cho *et al.,* 2013; Choi *et al.,* 2019; Kim *et al.,* 2020; Hwang *et al.,* 2022).

Hyperspectral imaging can also be used for diagnosis of plant pests (Choi *et al.,* 2019) and for sorting large quantities of non-germinating lettuce seeds (Ahn *et al.,* 2012). Hyperspectral technology has also been used to phenotype tomato and chili. Cho *et al.* (2013) used hyperspectral imaging to identify the wavelengths at which the phenotypes of tomatoes and chilies were more sensitive to different water stress intensities.

2.2.5. Infrared Thermal Imaging

Infrared thermal imaging utilizes crop temperature as an indicator of physiological information important for crop management (Chaerle *et al.,* 2007). Measuring crop temperature or leaf surface temperature is necessary because crops absorb carbon dioxide for photosynthesis through leaf stomata, release oxygen, and regulate their temperature through transpiration (Chéné *et al.,* 2012). Stomata in plants regulate stomatal opening and closing, so stomatal conductance can be used as an indirect diagnostic to determine the physiological state of the plant (Fahlgren *et al.,* 2015). Stomatal conductance is necessary to determine the effects and magnitude of biotic and abiotic stresses on physiological phenomena, and can be used to assess plant development, growth, and water and salinity (Chéné *et al.,* 2012; Fahlgren *et al.,* 2015), stress (Jeong *et al.,* 2019), and viral infections (Kim & Lee, 2020), and are often used for highly predictive and early response detection. Crops tend to show a temporary increase in temperature when stressed (Kim *et al.,* 2015), and infected areas show a decrease in temperature, resulting in the appearance of black spots, which can be seen through infrared thermal imaging.

The Crop Water Stress Index (CWSI), developed in the 1980s to quantitatively express water stress in plants, can identify physiological phenomena such as crop stress (Jeong *et al.,* 2018). However, this instrument uses a chambered gas-exchange analysis system, which is difficult to handle and does not allow for spatial variation and continuous observation (Na *et al.,* 2020). However, infrared thermometers or thermal imaging cameras can compensate for these shortcomings and are expected to contribute to crop stress monitoring.

2.2.6. X-ray CT and MRI imaging

Visual, near-infrared, fluorescence, hyperspectral, and infrared thermal imaging, which are methods for observing plants through imaging, can observe the aboveground parts of plants (Noh *et al.,* 2018). The underground part of the plant can also provide a wealth of information about the plant, but it is not as easy to observe. In most cases, observations of underground phenotypes are performed in destructive and artificial environments, such as excavating roots from the ground, using transparent culture media instead of soil, or using 2D growth monitors (Metzner *et al.,* 2015).

Current methods for non-destructive observation of the underground parts of plants include X-ray computed tomography (CT), magnetic resonance imaging (MRI), and neutron computed tomography (NCT) (Metzner *et al.,* 2015). Once a plant's roots are imaged with these methods, their parameters can be combined and quantitatively analyzed to predict plant health by using a standardized set of features for root size, location, and shape (Schulz *et al.,* 2013). We can then hypothesize that genetic traits correlate with features seen in root imaging.

Of these, neutron tomography requires a nuclear reactor or high-energy molecular accelerator, while X-ray CT and MRI are expensive to use, but their use by botanists is steadily increasing (Li *et al.,* 2014; Metzner *et al.,* 2015). X-ray CT utilizes a higher dose of radiation than conventional X-ray machines and has recently been utilized for applications in botany, allowing for the observation of lateral root development or root growth (Kolhar & Jagtap, 2021). Hughes *et al.* (2017) used X-ray micro-CT images of wheat to measure parameters through grain morphometry, and Soltaninejad *et al.* (2019) showed that 3D root images can be created using a multiresolution Encoder-decoder network with CT images for volume segmentation of wheat roots. MRI generates a strong magnetic field and uses hydrogen to produce tomographic images, allowing for the identification of transverse, longitudinal, and frontal sections of the root. MRI is also used to detect damage caused by Heterodera schachtii and Rhizoctonia solani in sugar beet (Hillnhütter *et al.,* 2011). X-ray CT provides higher resolution, while MRI can detect root segments more sensitively than CT due to the stronger contrast between roots and soil (Flavel *et al.,* 2012; Mooney *et al.,* 2012). As a result, the combination of the two methods can be used to characterize the roots of a wide variety of plants, allowing for the comparison and analysis of objective root phenotype data with a combination of parameters.

2.3. Image-based phenotype advantages

Plant phenotyping has long been performed by farmers and breeders. In traditional phenotyping, morphological traits were performed manually, requiring labor, time, and resources to measure plant traits. However, the application of sensor technologies and algorithms for phenotyping is now being performed to overcome these shortcomings (Klose *et al.,* 2009). This technology provides multi-trait evaluation with automatic measurement and time saving, enabling uniform structure, non-destructive measurement, accurate results, and direct storage.

RGB image analysis provides an accurate and fast way to measure plant features (Tuberosa 2011). This analysis method is the most important technique for plant phenotyping.

Near-infrared (NIR) imaging provides detailed data on the water status of leaves (Eberius 2008). In particular, the phenonet sensor network, phenomobile, phenotower, and blimp are important tools that enable in situ plant phenotyping to study many plants simultaneously (http://www.plantphenomics.org).

Hyperspectral image analysis is one of the techniques that can formulate different metrics and then infer various morphological and physiological traits of plants (http://maizephenotyping.cimmyt.org/index.php). The spectral reflectance of plant structures allows for the monitoring of several dynamic complex traits in phenotyping. Spectrometers are used to measure spectral reflectance in the range of 350 to 2500 nm (Nasarudin & Shafri, 2011), and physiological changes in the crop canopy, including chlorophyll content, photosynthetic capacity, nitrogen and plant water status, and carotenoid content, are measured by spectral reflectance. These values can be used to determine green biomass, photosynthetic area of the canopy, photosynthetic radiation absorbed by the canopy, and canopy structure. Cereal yields can be obtained using spectral reflectance indices during different developmental stages of the crop (Fender *et al.,* 2006; Yazdanbakhsh & Fisahn 2012; O'Shaughnessy *et al.,* 2011; Mullan & Mullan 2012).

Infrared thermal imaging measurements can reveal the physiological state of a plant as a function of its temperature, primarily during transpiration through leaf stomata (Chaerle *et al*., 2007). The closure of stomata is an early response of plants facing drought stress, which is the cause of reduced transpiration. Leaf temperature increases locally, creating a spatial temperature pattern that can be visualized by thermal imaging (http://maizephenotyping.cimmyt.org/index.php). Thermal is a practical alternative to specific measurements because it can analyze the canopy temperature of a site in a short amount of time and can produce a contour of the site's characteristics (Cohen *et al*., 2005). Thanks to thermal imaging, different levels of water status can be defined in different environmental and greenhouse conditions (Grant *et al*., 2006), so thermal imaging systems allow for quick and rapid data collection from a single leaf or canopy area (Grant *et al*., 2007). The system also provides a large number of crop measurements at a low cost.

Fluorescence imaging methods can characterize plant health and photosynthetic activity. Fluorescence occurs when an object absorbs light of one wavelength and emits light of a different wavelength, and when measured, the fluorescence color can be represented as a color signal of plant problems, allowing for immediate analysis of plant health (http://www.plantphenomics.com).

X-ray CT and MRI imaging methods are mainly used to study plant roots. These methods allow you to see the 3D geometry of the roots as if they were growing in the soil.

These different ways of looking at the different growth conditions of a plant can yield a large amount of data. The proteins and metabolites of many samples can be informed by high-throughput phenotyping without the need for tissue extraction. With these technologies, data can be obtained from physiological measurements and in situ measurements, such as photosynthesis, nutrient uptake, and plant growth and development, as well as from high-throughput phenotyping, in areas where it is difficult to obtain quantified data with the naked eye (NIFA-NSF Phenomics

Report 2011).

2.4. Disadvantages of image-based phenotypes

Image-based phenotyping has advanced plant sciences by enabling the receipt of plant phenotypes as quantified data with high data throughput. It has also enabled data research through soil and crop analysis, modeling, and sensor technology to measure data in the field and laboratory. Image analysis of plants has enabled unbiased and faster trait evaluation by providing speed, accuracy, efficiency, and optimized time for crop management (Post 2011). Phenotyping techniques depend on some factors such as simulation, sensors, active mechanisms, high throughput, and field-based platforms (Post 2011). Plant temperature is an essential trait because it is used to identify certain physiological factors such as stomatal conductance, transpiration rate, plant water status, water use, leaf area index, and crop yield. However, plant phenotyping has some limitations such as the quality of measurable data, cost of data acquisition, and availability of data collection techniques and algorithms.

- First, pre-headings and morning readings are generally low due to low incidence of insolation and temperature (Pietragalla 2012).
- Second, phenotyping methods have difficulty accurately assessing plant condition due to seasonally varying temperatures (Furbank & Tester 2011).
- Third, when measuring plant condition, the photoperiod or the angle at which measurements are taken can vary, which negatively affects accurate plant temperature identification (Jones & Vaughan 2010).
- Fourth, the characterization of stomatal conductance is very important to indicate transpiration and gas movement in leaves, and this method can present some difficulties in the measurement time for gas activity. Because stomata are sensitive to external influences and stomatal conductance, they may show different responses on different leaves.

●Fifth, chlorophyll fluorescence is useful for indicating drought resistance and is one of the most used traits in plant phenotyping. The fluorescence parameter is easy to determine, but the predicted value can change during photosynthesis. In particular, changes in fluorescence lead to several inaccurate measurements when estimating the operating efficiency of a photosystem II (Furbank & Tester 2011).

●Sixth, chlorophyll content is an important characteristic to identify photosynthetic activity, but it is strongly influenced by environmental conditions. The angle, time of day, and leaf surface condition of sunlight can interfere with the measurement of chlorophyll content, and the position of the plant's leaves and the error of the chlorophyll meter negatively affect the measurement of chlorophyll content. Experiments with light interception in plants provide very useful information on crop growth and productivity and crop modeling (Rosati *et al.,* 2001).

However, measurements under field conditions are not straightforward and are often affected by environmental variability. Carbon isotope identification is useful for estimating water status and transpiration capacity. However, obtaining quantified data in this area is not easy. This is because it is costly and requires specialized data analysis.

Chapter II. Vegetative organs: Leaves, Stems

1. Introduction

Plant leaves are the photosynthesizing organs that are important for nutrient production and play an important role in survival and growth (Hong *et al*., 1997). In addition to this, leaves play several other roles, such as solar radiation, atmospheric humidity, temperature and turbulence, stomatal conditions, and water status of the plant. Leaves are an important part of the plant and have been studied extensively (Hong *et al*., 1997; Box, 2012).

Leaf size and structure can greatly affect photosynthesis and respiration. Leaf size can predict photosynthetic uptake, and the type of leaf structure can measure physiological activity (Box, 2012). Historically, measurements of plant leaves have been made with rulers and calipers, but it has been difficult to quantify other types of data besides leaf length, width, and thickness. Currently, a variety of imaging methods can be used to quantify leaf area, color, texture, perimeter, curve, thickness, and shape (Gelbukh *et al*., 2006; Tak *et al*., 2007; Granier *et al*., 2009; Nakayama *et al*., 2017; Zhuang *et al*., 2020).

The stem is an important link between root, plant, and atmosphere. It is the nutritional system of a plant, connected to the roots below and the leaves above, and determines the shape of the plant. Stems are the plant's nutritional organs that grow from the stem and produce new eyes and leaves every year, forming a water pipe (Kang, 2006). The role of the stem is to extend upward so that the leaves can photosynthesize well, and to connect with the roots so that they can absorb moisture well (Wilson *et al*., 1995; Burgess *et al*., 2006).

The length and width of the stems and stem determine the growth rate and yield of the plant. Longer stems allow the leaves to be in a better position to receive light and thus photosynthesize better, and conversely, shorter stems provide a more secure supply of water (Burgess *et al*., 2006). The width and thickness of the stems and stems determine the yield of the plant. Increased branching and stem length in potatoes leads to a differential increase in the number of fruits (Vos *et al*., 1992). Increasing stem height and width has been linked to plant growth duration and is also influenced by lodging-resistance (Shen *et al*., 2018).

The objective of this study is to conduct a phenotypic/morphological characterization and genetic diversity assessment of *Capsicum annuum* (chili) by examining 188 accessions of chili germplasm. This research aims to develop a comprehensive understanding of the morphological diversity within the species. By studying the diverse morphological traits, breeders can strategically select parental lines that possess specific traits of interest. Analyzing the morphology of leaves and stems provides valuable insights into the physiological characteristics and growth patterns of chili plants, contributing to improved crop management and optimization strategies. This knowledge can be utilized in targeted breeding programs to develop new chili varieties.

2. Materials and Methods

2.1. Chilies materials

In this study, a total of 188 accessions of *C. annuum* originating from 36 countries were analyzed. The source of the geographical origin data for each accession was the National Seed Resources (https://www.seed.go.kr/sites/seed/index.do) located at 300, Nongyeongim-ro, Deokjin-gu, Jeonju-si, Jeollabuk-do, Korea (35°49'51.6"N 127°03'46.0"E) (Fig. 1). Standardized cultivation methods created by the National Seed Resources were followed. The species and origin information of the resources are given in APPENDIX- I. Chili leaves were collected from mid-June through the chili's fruiting season and moved indoors to the studio, six leaves per resource, for reliable image extraction. Chili stems were collected from resources that were fully fruiting in early August, cut leaving 10 cm above the soil, and moved to the studio with three stems per resource.

In addition, all of the chili leaves and trigger fingers used in the filming were removed prior to filming to ensure that no foreign objects other than the crops would appear in the video.

Fig. 1. The field location of this study in Jeonju, South Korea.

2.2. Setting the studio and camera

Before imaging the chili leaves, an indoor studio (800*800*800mm) was set up to reduce the influence of ambient light, and an 18W class white (5600K) LED (CN-T96, Plastic, Korea) was used to adjust the required illumination to prevent distortion and damage to the data caused by shadows, and the background plate was made in-house in white considering the color of the chili leaves. A digital camera (EOS D200II, Lens EF-S 18-55mm, Canon, Japan) was used as the camera. This model has a CMOS sensor and is capable of 24.1 megapixels. The camera settings were an ISO value of 200, a focal length of 35m, and an exposure time of 1/25. Due to the convex lens of the camera, the center of the lens is thicker than the edges, which can cause data distortion when measuring. To avoid this, we used the in-camera distortion correction function.

The chili plant was imaged with the lateral stem removed except for the main stem. This was done in the same indoor studio where the chili leaves were photographed, and the lighting was repositioned to minimize shadows from the chili trigger features. The camera model is the same as above. The camera settings were ISO of 100, the focal length of 18mm, and exposure time of 1/13. Due to the convex lens of the camera, the center of the image may appear thicker than the edges, causing data distortion when measuring. To avoid this, we used the in-camera distortion correction function. The background was made in-house in black to match the color of the chili mill.

To capture the chili leaves and mills, we made our own 3D panels to give us a sense of their actual size. On the panel, name tags corresponding to the crops and four different colors of Grayscale Calibration (https://www.group8tech.com/gray-scale-calibration) were placed in the same position, and a QR code was created and used to fix the position. Four grayscale calibrations of 10mm each were made and used for scale calibration.

2.3. Preprocessing (Common)

2.3.1. White balance

The white balance was adjusted using the RAW file saved at the time of the shooting. A RAW file is uncompressed and unprocessed data obtained through DSRL (http://www.adobe.com/kr/creativecloud/filetype/image/raw.html). That is, since it is high quality original data with no loss of quality, it is suitable for adjusting the white balance. However, since the RAW file is not compressed, the file is heavy and has compatibility issues. Therefore, the white-balanced RAW file was converted into a JPEG format suitable for image processing.

2.3.2. File renaming

When shooting, all files are saved with a random file name designated by DSRL. Therefore, for data classification, the file name was changed to a name that includes resource information.

After recognizing the resource number of the label in the photo using the OCR API, it was matched one-to-one with the resource list Excel file to bring the IT number and change it to a file name. When the label was printed in advance, the font size of the resource number was increased and RED was used, so RED was used for primary detection and secondary OCR was used to extract the numbers. For reference, OCR refers to the process of converting a text image into a machine-readable text format (https://aws.amazon.com/en/what-is/ocr/).

2.4. Image Processing

2.4.1. Leaves

2.4.1.1. Object Extraction

The leaves were extracted by finding the color threshold value of the leaves using ImageJ2 (Fiji) software. The images below are the original and threshold mask images (Fig. 2).

2.4.1.2. Parameter Computation

The parameters we need to find were the leaf width, length, and area. Here, the leaf refers to the leaf surface area excluding the leaf stem. Therefore, the leaf stem was removed using Jack's triangle algorithm (https://journals. sagepub.com/doi/pdf/10.1177/25.7.70454). After that, by calling through the cv2.FitEllipsse() function. And the area of the leaf was obtained through the cv2.contourArea() function. On the other hand, since these values are in pixels, they must be converted to mm. Since we know the reference size through the panel, we can find the scaling factor. Therefore, this value was multiplied to finally obtain all parameter values.

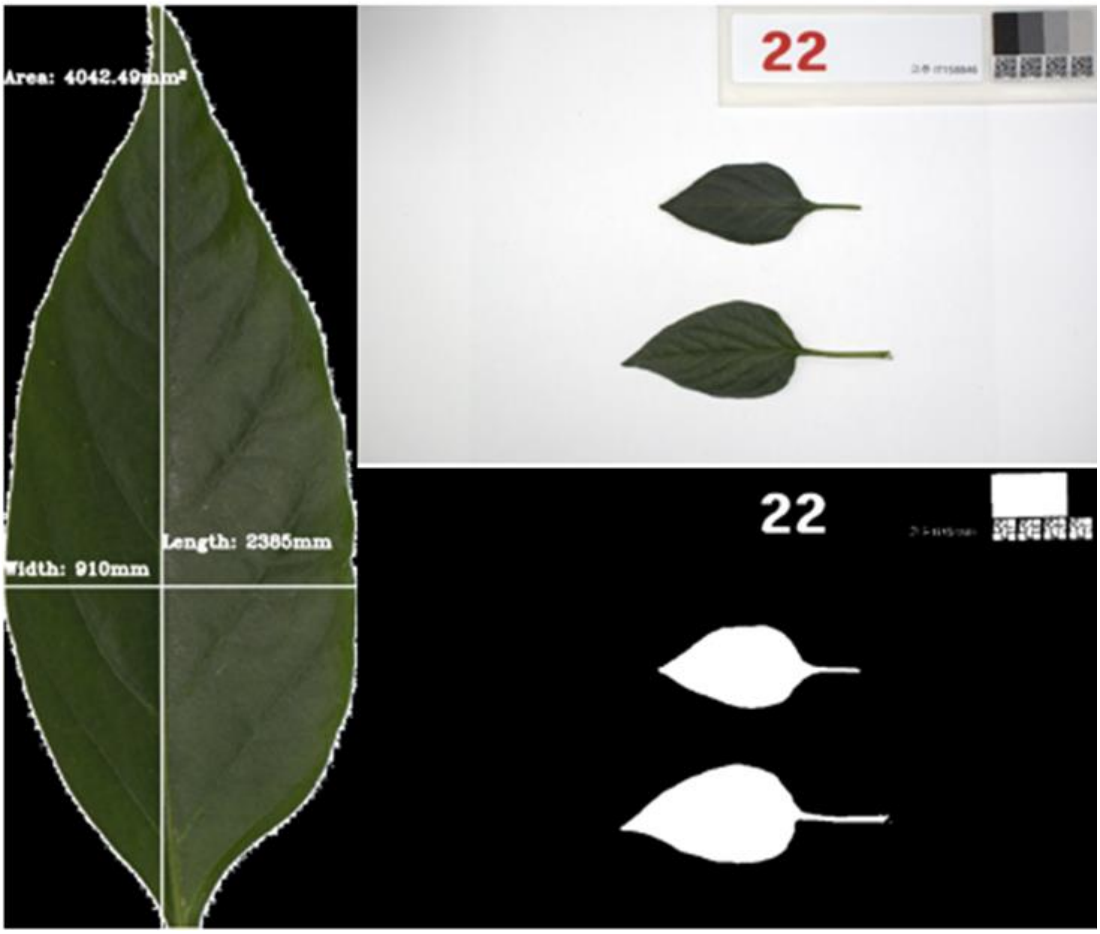


Fig. 2. Representative picture showing the extraction of leaves color threshold value using ImageJ2 (Fiji) software.

2.4.2. Stems

2.4.2.1. Object extraction

The stems were extracted by determining the color threshold value of the stems using the image (Fig. 3).

2.4.2.2. Parameter computation

The parameters we need to find were the length, thickness, and angle of the ladder. Here, the length of the bride means the length from the stem point. And the angle of the Y-shape knob, means the angle that spreads from the fork. First, by calling the OpenCV library of Python, the cv2.convexityDefects() function was used to obtain the divergence point of the bridge and both ends extending from the divergence point. The angle was obtained through these three points. Also, the bounding box in the figure below was drawn using the cv2.minRectArea() function. The thickness and length were calculated through the coordinates and bifurcation points of this box (Fig. 4). On the other hand, since these values are in pixels, they must be converted to mm. Since we know the reference size through the panel, we can find the scaling factor. Therefore, this value was multiplied to finally obtain all parameter values.

Fig. 3. Representative picture showing the extraction of stem color threshold value using ImageJ2 (Fiji) software.

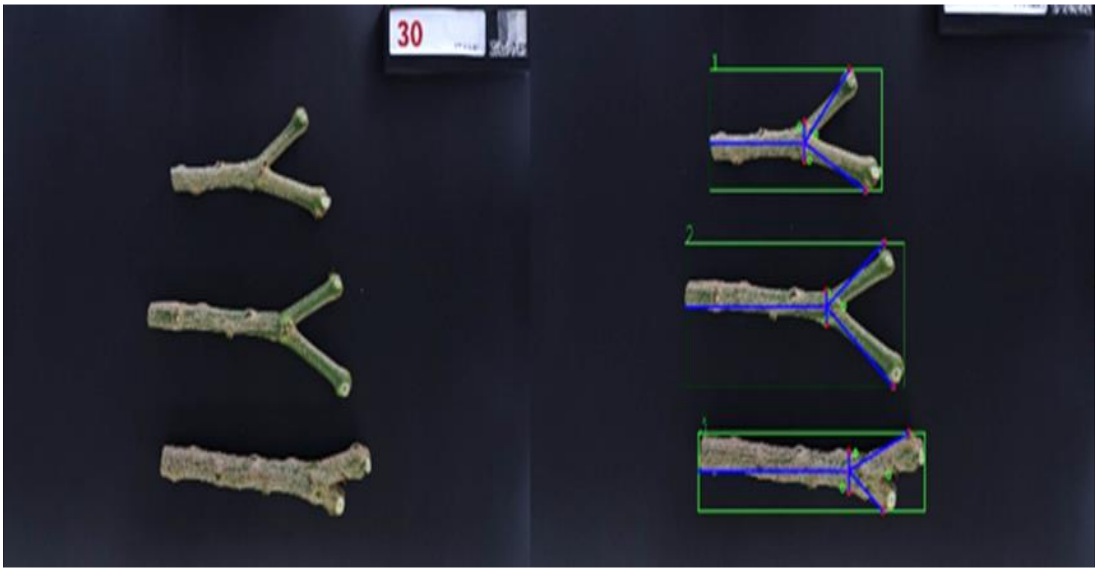


Fig. 4. Representative picture showing the measurement of stem thickness, length and angle using ImageJ2 (Fiji) software.

2.5. Statistical analysis

All statistical analysis was performed by "R" software (Ver. 4.2.2, R Foundation for Statistical Computing, Boston). The data sets were checked for normality by the Shapiro-Wilk test. The data sets of each trait showed a normal distribution, the parametric One-way ANOVA test followed by the Fisher's least significant difference (LSD) post hoc test was used to compare measured traits of 188 entries of chili. For correlation analysis was carried out with the Pearson correlation test.

For a more comprehensive description of the results, the K-Mean cluster and principal component analysis (PCA) were used to summarize the relationship among the measure traits. The cluster and PCA plots were generated through the "factoextra" R package.

3. Results

The study analyzed 188 accessions of *C. annuum* from 36 countries (APPENDIX- I), and the geographic origin data for each accession was obtained from the National Seed Resources in Korea (Table 1). Standardized cultivation methods were followed for each resource. The study collected chili leaves and stems from the resources, with six leaves and three stems collected per resource, respectively. The leaves were collected from mid-June through the chilies' fruiting season and moved indoors for reliable image extraction, while the stems were collected from resources that were fully fruiting in early August.

Table 1. The number of the accessions for each country.

Species	Origins (No. of accession)
C. annuum(188)	BGR(11), BOL(1), BRA(3), CHN(4), CUB(1), ECU(1), FRA(3), GEO(1), GTM(1), HUN(1), IDN(2), IND(7), IRN(3), ITA(1), JPN(1), KOR(21), LAO(8), LBY(1), LKA(1), MEX(7), MYS(8), NLD(1), NPL(2), PAK(1), PRI(1), RUS(8), THA(4), TUR(1), TWN(1), UKR(1), UNK(55), USA(25), UZB(8), VNM(14), ZMB(5), unknown(2)

Leaf Traits

The data indicated that there was significant diversity in the qualitative characteristics such as leaf area, length, and width. The average leaf area was calculated to be in the range of 3,781 to 6,302 (Mean = 5,317mm^2) square millimeters, with a CV value of 0.38 and SD of 2,040 (LSD=1,090.331). While the average leaf length ranged between 100 to 166 millimeters (LSD=14.645) and the average leaf width ranged from 45 to 75 millimeters (LSD=7.478) as mentioned in Table 2 and Table 3. The box plot in Fig. 5 shows the information related to the mean leaf area, width, and length.

Bivariate analysis indicates a strong positive correlation between the two variables among leaf area and leaf length, leaf area and leaf width, and leaf length and leaf width the correlation matrix attached in Fig. 6. This meant that the two variables tend to increase or decrease together, and there was a clear linear relationship between them. In our study, there was a strong correlation between the studied traits as shown in Fig. 6.

The study was conducted to determine the degree of variation between different genotypes and group them based on their similarities. To achieve this, we examined the phenotypic variability among 118 genotypes and used dendrograms to show the phenotypic relationships between them. We found significant differences in traits between the different clusters formed. In this analysis of leaf traits in 188 genotypes, two distinct clusters were formed (Fig. 7a), with clusters one and two consisting of the accessions/genotypes listed in Fig. 7b. The number of clusters was determined using K pot analysis, and a value of 2 was chosen based on a higher ΔK value relative to the number of clusters suggested by R software (Fig. 8).

PCA is a statistical method that determines how much each variable contributes to the overall variation along the principal axes. The eigenvalues obtained from PCA are commonly used to select the most discriminating factors among the variables. The sum of all the eigenvalues is usually equal to the total number of variables. For instance, in this analysis, the first principal component explained 2.81 times more variance than the original variables. The leaf area and width were strongly correlated as in shown in PCA1 (93.8%). The results showed that the first two principal components explained 93.8% and 5.8 % of the phenotypic variation (Fig. 9). Leaf length had greater variance than area and width.

Table 2. The statistical analysis of three leaf traits studied in the 188 genotypes of chili germplasm.

	Leaf Area	Leaf Length	Leaf Width
Min	1,507.45	67.25	32.27
Max	11,541.18	190.75	100.59
Mean	5,317.61	133.32	61.79
Median	5,031.4	133.04	60.28
SD	2,040.42	23.91	13.83
CV	0.38	0.17	0.22

Table 3. The statistical analysis of leaf traits.

Trait	Source	DF	Sum of Squares	Mean Squares	F value	Pr>F		LSD
Leaf area	Rep.	5	5.10E+07	10,207,055	2.088	6.45E-02	NS	
	Entry	187	4.64E+09	24,790,593	26.98	2.00E-16	***	1,090.33
Leaf length	Rep.	5	12,216	2443.3	3.48	0.00396	**	
	Entry	187	638,255	3413	20.53	2.00E-16	***	14.64
Leaf width	Rep.	5	2078	415.5	1.843	1.02E-01	NS	
	Entry	187	213,204	1,140.1	26.68	2.00E-16	***	7.47

** and *** Significant at the 0.01 and 0.001 probability level, respectively.

NS = Nonsignificant at $P < 0.05$.

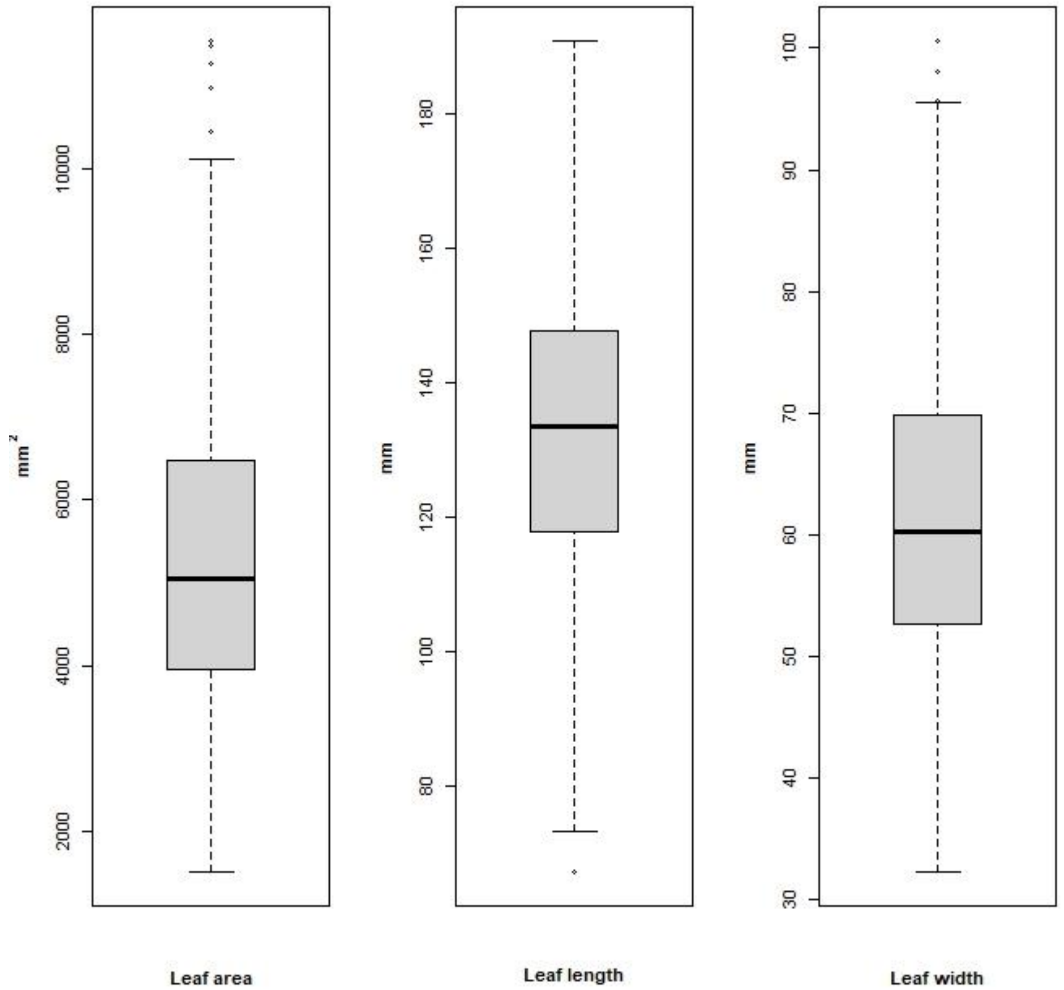


Fig. 5. Box plot showing the average (mean) of different leaf traits.

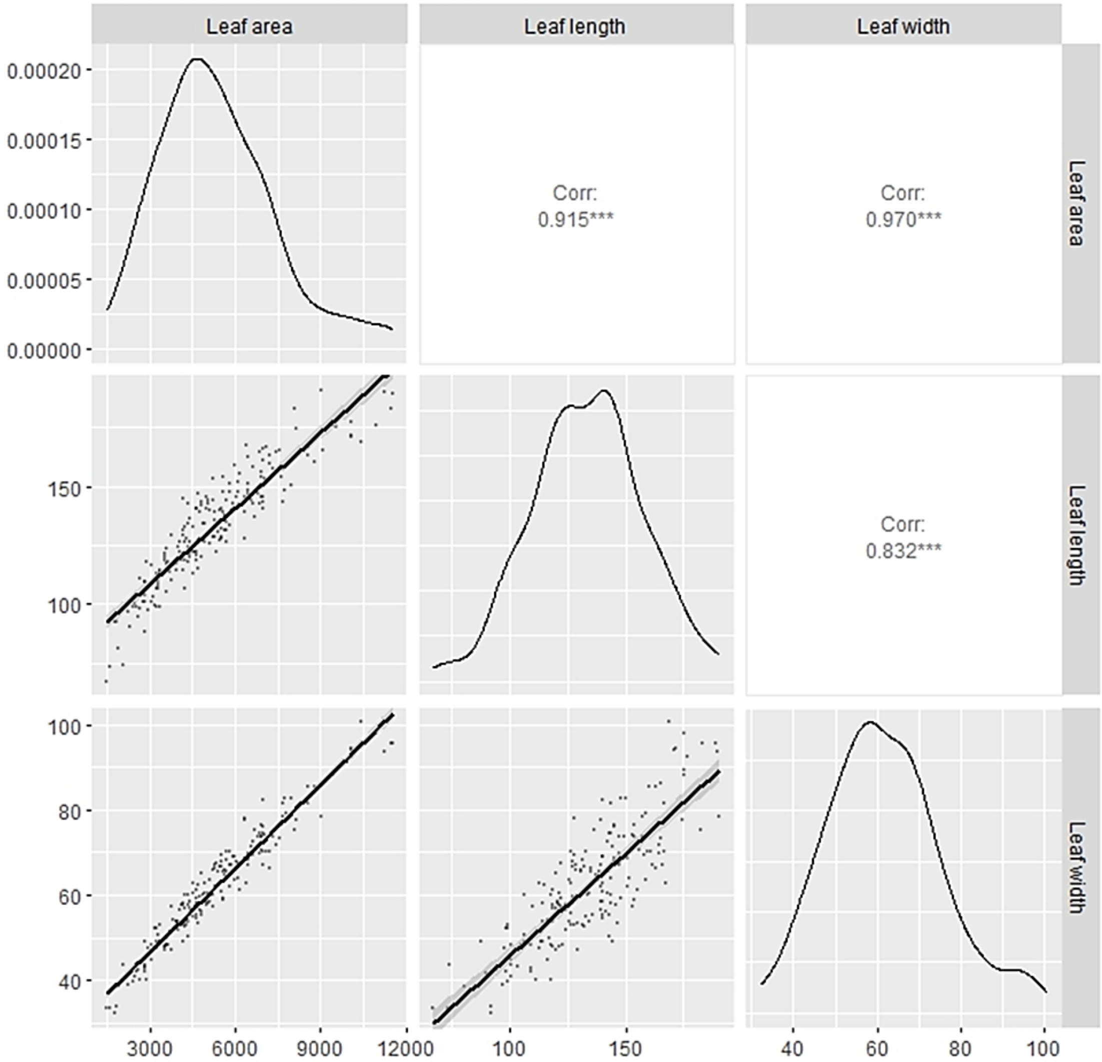
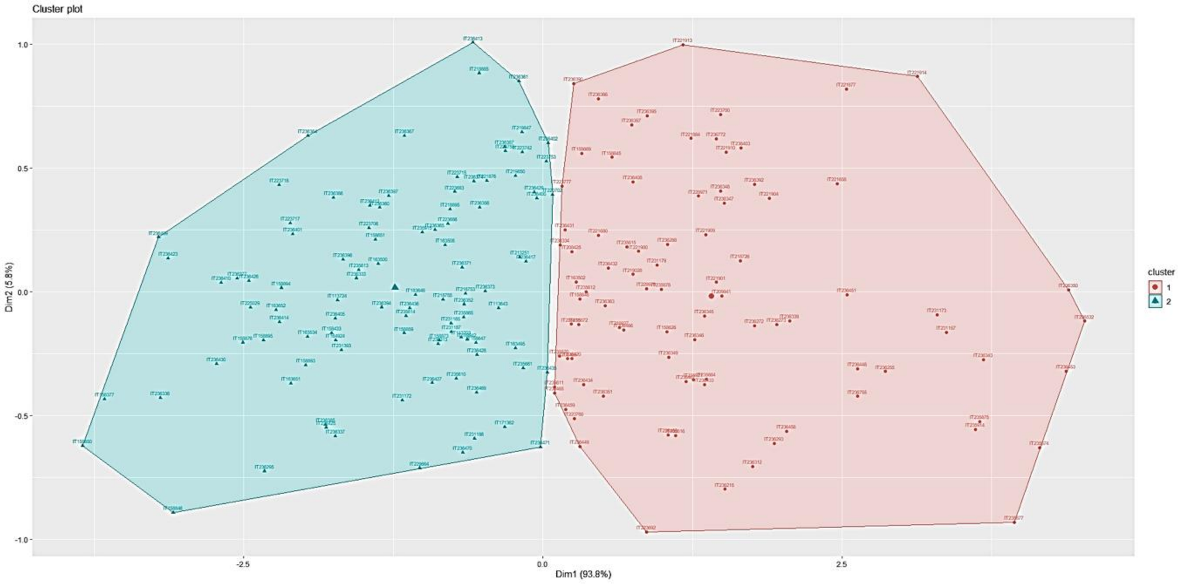


Fig. 6. Bivariate analysis showing the correlation of chili leaf traits.

*** Significant at the 0.001 probability level, respectively.

a.



b.

Leaf

Cluster 1				Cluster 2				
IT236453	IT231179	IT236288	IT158626	IT113643	IT229664	IT236423	IT183651	IT236365
IT236458	IT235611	IT236293	IT158645	IT113703	IT231165	IT236425	IT183652	IT236367
IT236459	IT235612	IT236312	IT158648	IT113724	IT231172	IT236426	IT189942	IT236371
IT236460	IT235615	IT236334	IT158669	IT158377	IT231186	IT236427	IT213251	IT236373
IT236465	IT235616	IT236339	IT163502	IT158433	IT231187	IT236428	IT218753	IT236374
IT236466	IT235618	IT236343	IT208425	IT158647	IT231393	IT236429	IT218755	IT236377
IT236467	IT235664	IT236345	IT209941	IT158651	IT235610	IT236430	IT218885	IT236385
IT236468	IT235870	IT236346	IT218726	IT158846	IT235613	IT236435	IT218895	IT236386
IT236532	IT235872	IT236347	IT218937	IT158850	IT235614	IT236436	IT219847	IT236387
IT236755	IT235874	IT236348	IT219028	IT158859	IT235661	IT236469	IT219850	IT236394
IT236772	IT235875	IT236349	IT221658	IT158873	IT235865	IT236470	IT221876	IT236396
IT236215	IT235877	IT236350	IT221680	IT158876	IT235915	IT236471	IT223683	IT236397
IT236255	IT235878	IT236351	IT221877	IT158893	IT236295	IT236400	IT223686	
IT236272	IT235914	IT236357	IT221884	IT158894	IT236313	IT236401	IT223702	
IT236273	IT235921	IT236363	IT221900	IT158895	IT236333	IT236402	IT223706	
IT236432	IT223777	IT236366	IT221901	IT163495	IT236336	IT236405	IT223715	
IT236433	IT223780	IT236390	IT221904	IT163500	IT236337	IT236409	IT223717	
IT236434	IT228971	IT236392	IT221909	IT163508	IT236352	IT236410	IT223718	
IT236448	IT229979	IT236395	IT221910	IT163534	IT236356	IT236412	IT223742	
IT236449	IT231157	IT236403	IT221913	IT164924	IT236360	IT236413	IT223753	
IT236451	IT231173	IT236408	IT221914	IT171362	IT236361	IT236414	IT223755	
IT236431	IT223700	IT236420	IT223692	IT183648	IT236364	IT236417	IT225029	

Fig. 7. Dendrograms showing distribution of chili germplasm into 2 clusters based on leaf traits (a), Distribution of accessions in two different clusters (b).

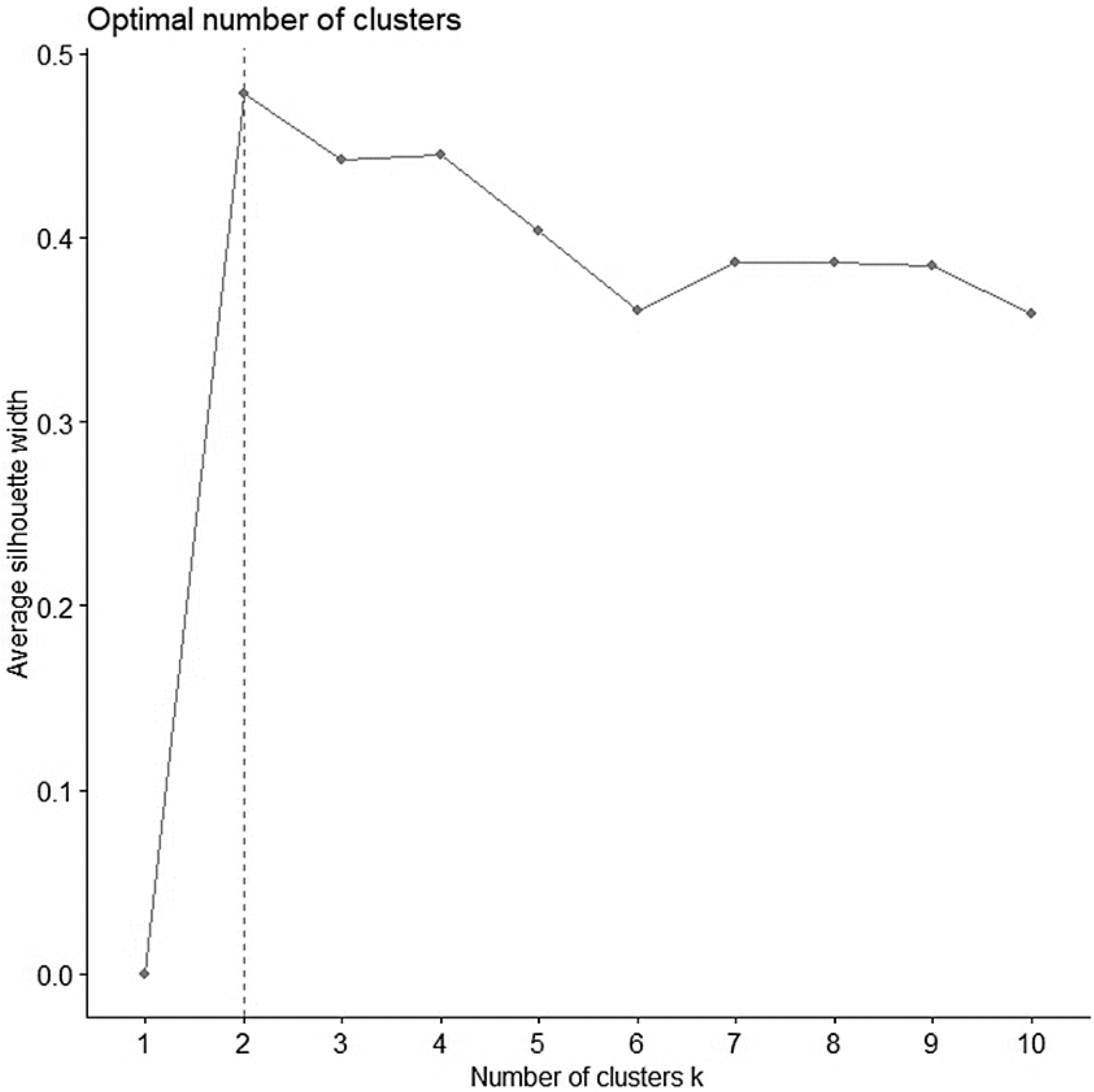


Fig. 8. ΔK peak value of 0.5 among the assumed K showing peak value at 2.

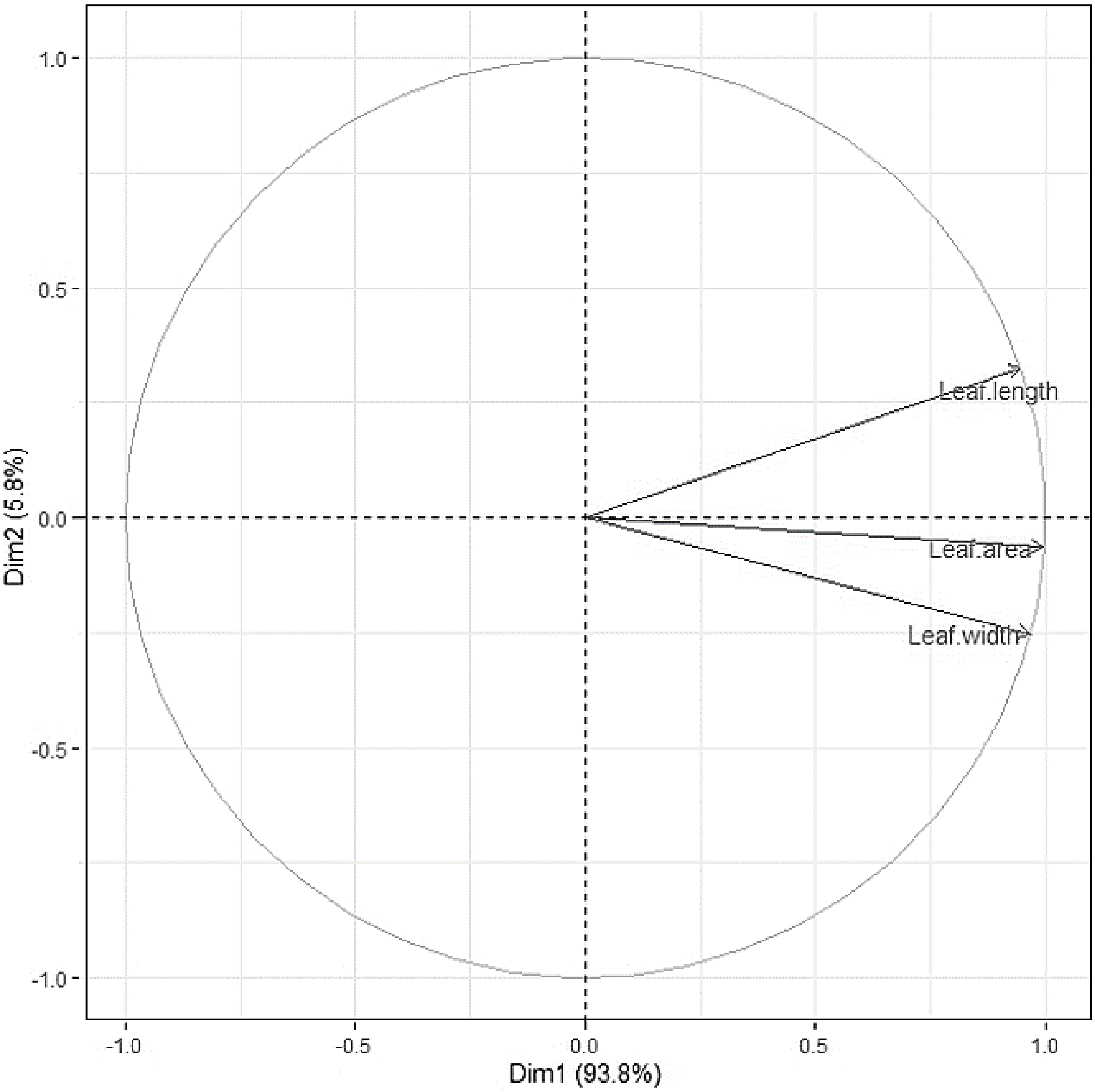


Fig. 9. Principal coordinate analysis showing the clustering of two chili populations.

Stem Traits

The data indicates that there was also significant diversity in the qualitative characteristics such as stem angle, length, and thickness. The average stem angle was calculated to be in the range of 41 to 69 (Mean = 56°) degrees, with a CV of 0.15 and an SD of 8.96 (LSD=19.406). While the average stem length ranged between 180 to 301 millimeters SD of 71 and a CV value of 0.28 (LSD=59.239) and the average stem thickness ranged from 15 to 26 millimeters mean of 21 and a CV value of 0.22 (LSD=14.370) Table 4, 5 and Fig. 10.

Bivariate analysis indicated the positive correlation between stem angle and stem length and negative correlation between stem thickness and stem angle. This means that the two variables tend to increase or decrease together, and when one increases, the other tends to decrease. It means that there is a clear linear relationship between them and a weak linear relationship. In our study, there was a correlation among the studied characteristics Figure 11.

The study was conducted to determine the degree of variation between different genotypes and group them based on their similarities. To achieve this, we examined the phenotypic variability among 118 genotypes and used dendrograms to show the phenotypic relationships among them. We found significant differences in traits among the different clusters formed. In this analysis of stem traits in 188 genotypes, three distinct clusters were formed, with clusters one, two, and three consisting of the accessions/genotypes (Fig. 12). The number of clusters was determined using K pot analysis, and a value of 3 was chosen based on a higher ΔK value relative to the number of clusters suggested by R software (Fig. 13a and 13b).

PCA is a statistical method that determines the variable that contributes to the overall variation along the principal axes in the case of stem length, angle, and thickness. In this analysis, the first principal component had an eigenvalue of 1.39. The two principal components with eigenvalues greater than one account for 46.51% of the total variation. The results showed that the first two principal components explained 46.5% and 36.2% of the phenotypic variation, respectively in between the stem traits (Fig. 14).

We also conducted a principal component analysis between the leaf traits and stem traits to determine how the genotypes were grouped based on their related traits. The results showed that the first two principal components explained 46.5% and 36.2% of the phenotypic variation, respectively. PC1 indicated a good correlation among leaf length, area, and width among the chili genotypes with positive coefficients, while PC2 represented the variation or divergence in stem-related traits, such as length, angle, and thickness, having a weaker correlation among traits. Overall, there was a strong correlation between leaf traits.

Table 4. The statistical analysis of three stem traits studied in the 188 genotypes of chili germplasm.

	Stem length	Stem thickness	Stem angle
Median	241.03	20.81	55.76
Sum	46995.46	3999.84	10474.3
Min	140.69	13.08	35.63
Max	553.65	52.75	99.51
Mean	251.12	21.38	56.03
SD	71.19	4.76	8.96
CV	0.28	0.22	0.15

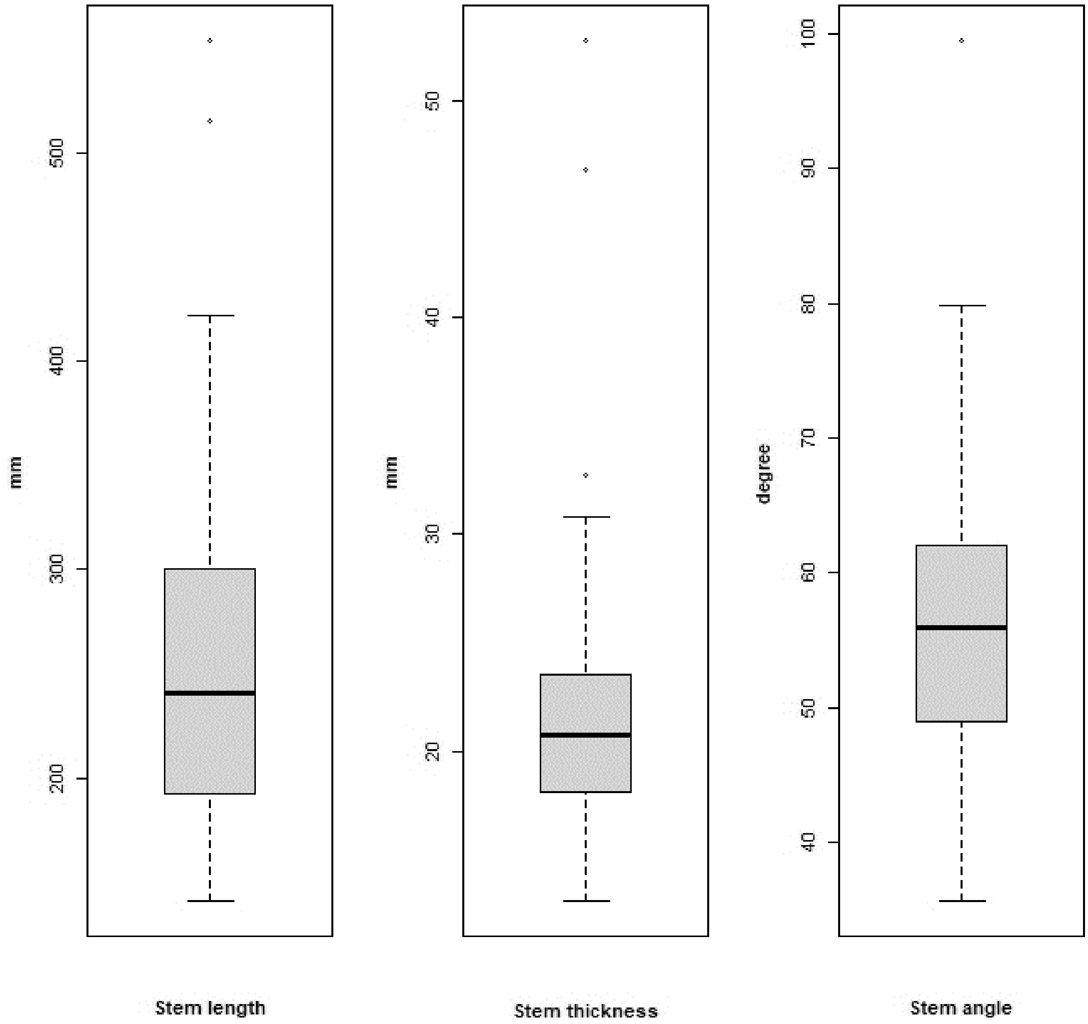


Fig. 10. Box plot showing the average (mean) of different traits in the stem.

Table 5. The statistical analysis of stem traits.

Trait	Source	DF	Sum of Squares	Mean Squares	F value	Pr>F		LSD
Stem length	Rep.	2	8018	4009	0.58	0.56	NS	
	Entry	187	3350104	17915	13.51	2.00E-16	***	59.24
Stem thickness	Rep.	2	204	102.21	1.17	3.11E-01	NS	
	Entry	187	20034	107.1	1.38	4.33E-03	**	14.37
Stem angle	Rep.	2	28	13.89	0.07	0.929	NS	
	Entry	187	50905	272.2	1.86	2.08E-07	***	19.40

** and *** Significant at the 0.01 and 0.001 probability level, respectively.

NS = Nonsignificant at $P < 0.05$.

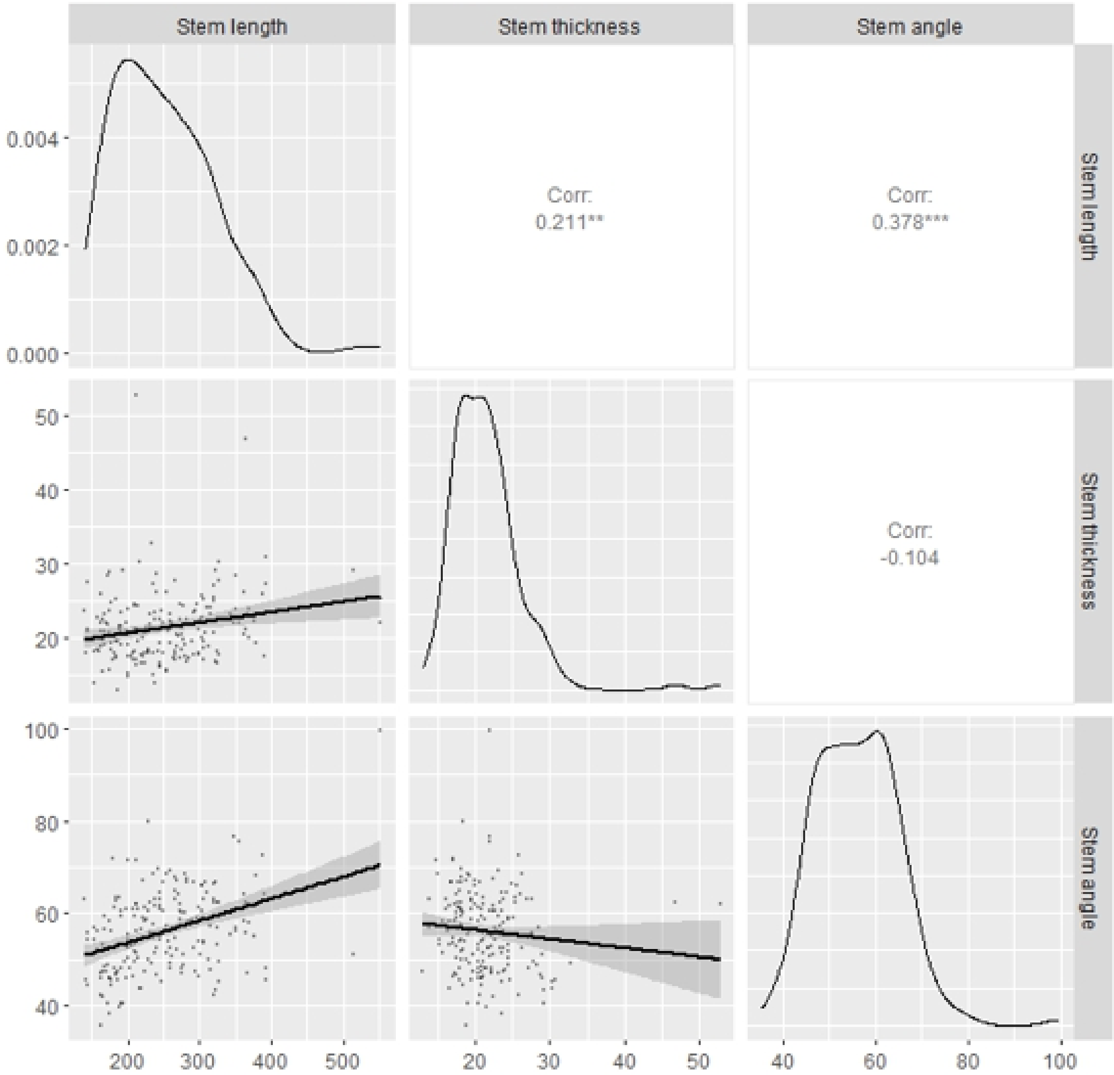


Fig. 11. Bivariate analysis showing the correlation between chili stems.

** and *** Significant at the 0.01 and 0.001 probability level, respectively.

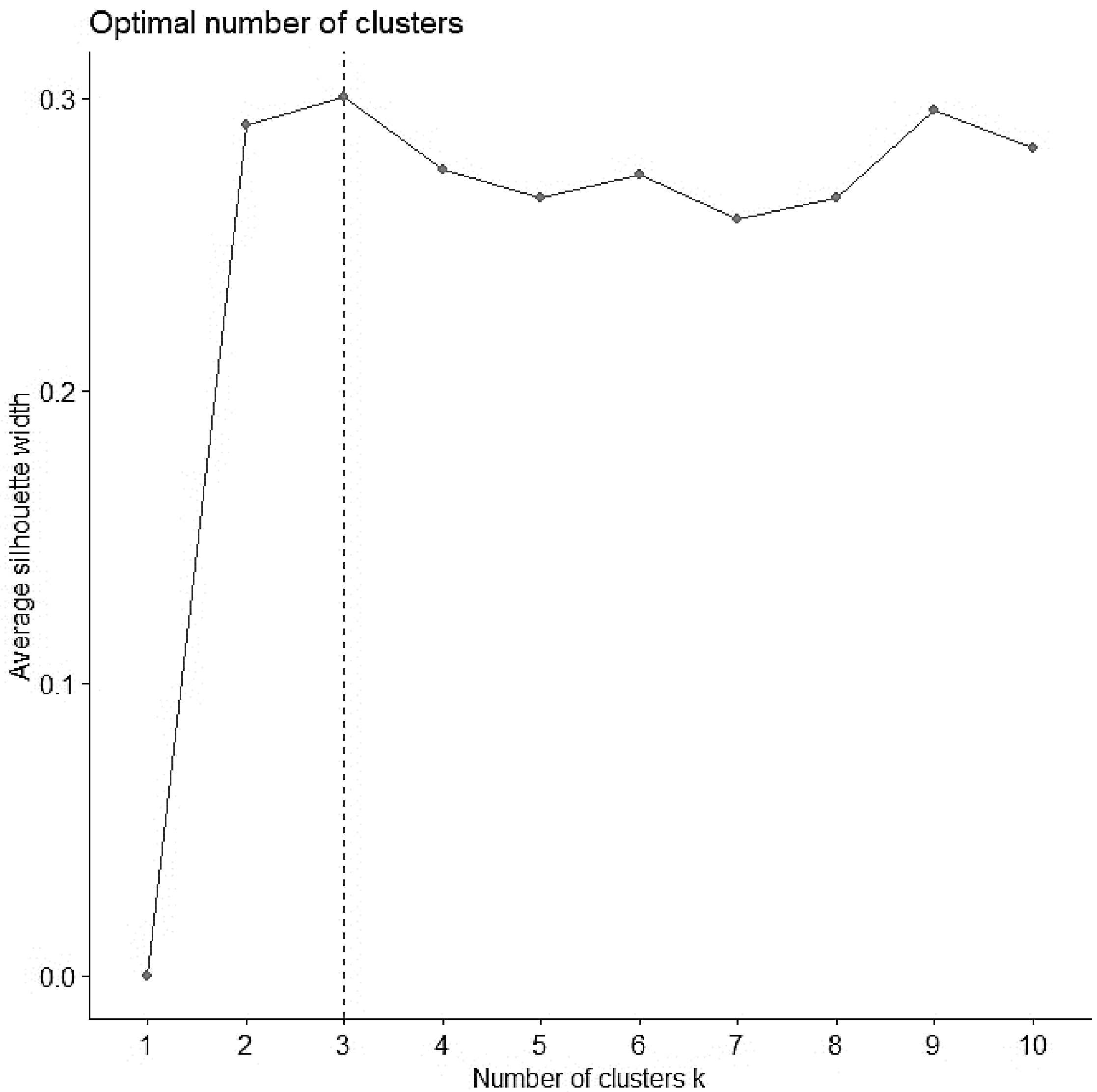
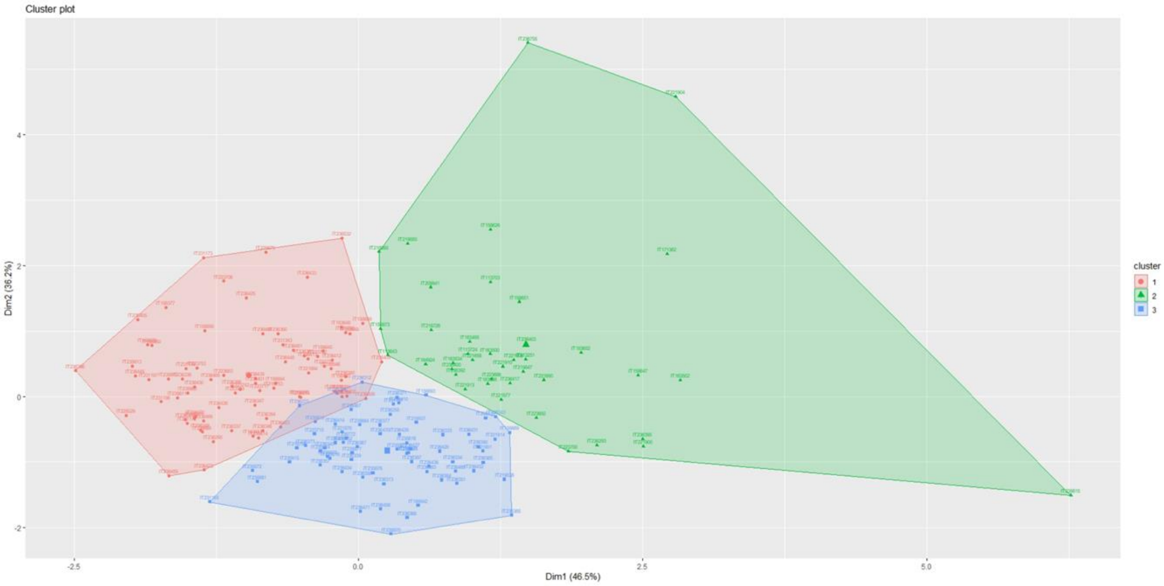


Fig. 12. ΔK peak value of 0.3 among the assumed K showing peak value at 3.

a.



b.

Stem

Cluster 1				Cluster 2				Cluster 3	
IT236215	IT158377	IT236409	IT223742	IT158669	IT236356	IT235874	IT236434	IT113643	IT219850
IT236288	IT158433	IT236412	IT223753	IT158893	IT236357	IT235875	IT236436	IT113703	IT221658
IT236295	IT158645	IT236413	IT223755	IT189942	IT236363	IT235877	IT236458	IT113724	IT221680
IT236336	IT158648	IT236420	IT223777	IT208425	IT236364	IT235878	IT236465	IT158626	IT221877
IT236337	IT158846	IT236423	IT223780	IT218755	IT236365	IT235914	IT236466	IT158647	IT221900
IT236346	IT158850	IT236425	IT225029	IT218937	IT236366	IT235915	IT236467	IT158651	IT221904
IT236347	IT158859	IT236426	IT228971	IT219028	IT236367	IT235921	IT236470	IT158873	IT221909
IT236348	IT158876	IT236430	IT229664	IT221876	IT236371	IT236255	IT236471	IT163495	IT221910
IT236350	IT158894	IT236433	IT229979	IT221901	IT236377	IT236272	IT236772	IT163500	IT221913
IT236360	IT158895	IT236435	IT231172	IT221914	IT236385	IT236273		IT163502	IT223686
IT236361	IT183648	IT236448	IT231173	IT223715	IT236387	IT236312		IT163508	IT223692
IT236373	IT183651	IT236449	IT231179	IT231157	IT236390	IT236313		IT163534	IT223700
IT236374	IT218753	IT236451	IT231186	IT231165	IT236397	IT236333		IT164924	IT235615
IT236386	IT218895	IT236453	IT231187	IT235612	IT236410	IT236334		IT171362	IT236293
IT236394	IT221884	IT236459	IT231393	IT235616	IT236414	IT236339		IT183652	IT236392
IT236396	IT223683	IT236460	IT235610	IT235618	IT236427	IT236343		IT209941	IT236395
IT236401	IT223702	IT236468	IT235611	IT235661	IT236428	IT236345		IT213251	IT236400
IT236402	IT223706	IT236469	IT235613	IT235664	IT236429	IT236349		IT218726	IT236403
IT236405	IT223717	IT236532	IT235614	IT235870	IT236431	IT236351		IT218885	IT236417
IT236408	IT223718	IT235865		IT235872	IT236432	IT236352		IT219847	IT236755

Fig. 13. Dendrograms showing distribution of chili germplasm into 2 clusters based on leaf traits (a), Distribution of accessions in 3 different clusters based on stem traits (b).

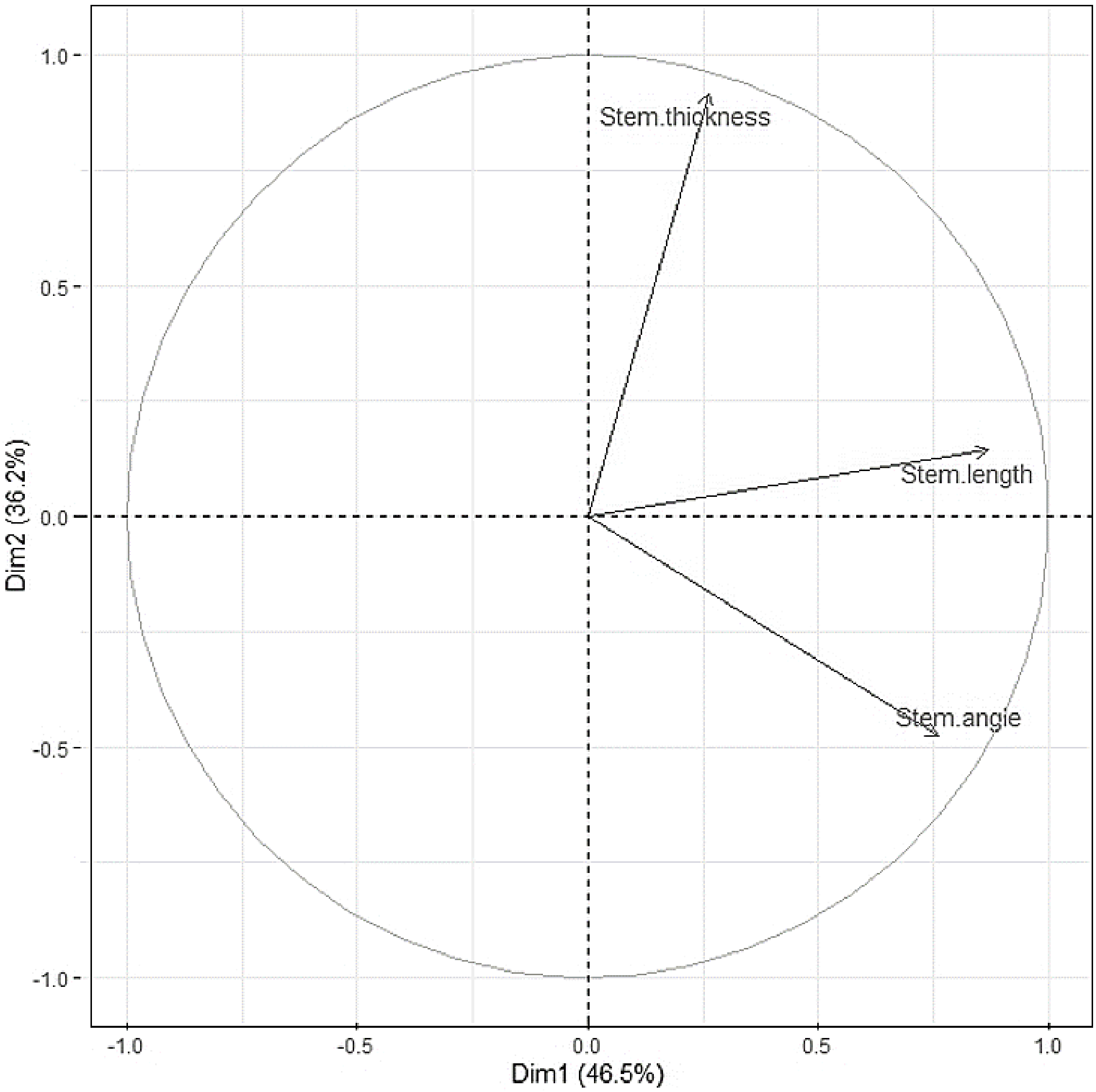


Fig. 14. Principal coordinate analysis showing the clustering of stem traits into separate coordinates.

4. Discussion

Plants exhibit a wide range of phenotypic variation due to the interaction between genetic factors and environmental conditions during their long-term evolution. The extent of phenotypic variation in a population may reflect its level of genetic diversity. Evaluating plant traits through phenotyping is a direct approach to assessing the diversity of forest germplasm resources, which is essential for their proper breeding and conservation (Legendre *et al.,* 1989; Li *et al.,* 2022). It is crucial to comprehend the genetic and phenotypic composition of populations and investigate genetic and phenotypic parameters to ensure the efficient management of genetic resources. This initial step is necessary for any domestication process. Variability within core germplasm collections is essential for any domestication work.

This study conducted a comprehensive evaluation of the variation in three phenotypic traits of leaves among 188 genotypes. The study further investigated the association between these traits and the factors influencing the phenotypic variation. The values for leaf size were greater than those reported by Zahidi and Bani-Aameur for both simple and clustered leaves (Zahidi *et al.,* 2013). In addition, our population exhibited higher variability in simple and clustered leaf width, as well as a width-to-length ratio.

In this study, the coefficient of variation (CV) was used to assess the level of variation in germplasm for each trait. The results showed that Leaf Area, Leaf Length, and Leaf Width exhibited good variability among the two populations (Clusters), with CV values of 0.38, 0.17, and 0.22, respectively. Leaves play a crucial role in the long-term adaptation, survival, and evolution of plants, which may explain their abundant variation among natural populations' traits of interest. The bivariate experiments also confirmed that leaf traits had the highest amount of variation. The mean CV of leaf traits in chili germplasm was considerably higher, indicating that leaf traits were more susceptible to environmental factors. However, this may also be due in part to genetic background differences among the studied genotypes. Overall, the high variability observed in leaf traits underscores their importance in the assessment and conservation of plant germplasm resources (Du *et al.,* 2019; Deng *et al.,* 2021; Meng *et al.,* 2022). PCA and clustering analysis between leaf and stem traits indicated a good correlation among leaf traits while having a weaker correlation among stem traits. Overall, there was a strong correlation between leaf traits but there was a greater divergence between the stem traits.

The phenotypic differentiation coefficient is a measure of how much a species differs in traits, with higher coefficients indicating a greater likelihood of population differentiation. The prevalence of larger leaves in warmer environments has been partially explained by the lack of frost danger, as night-time conditions in colder climates cause greater cooling of large leaves, thereby imposing a constraint on maximum leaf area. In warmer environments, however, large leaves facilitate effective transpirational cooling. On the other hand, small leaves were a common feature of dry environments, and the negative relationship between leaf area and aridity was not surprising (Wright *et al.,* 2017). The commonly accepted explanation is that restricted transpiration in dry climates prevents the survival of large leaves, as they would be forced to reach excessively high daytime temperatures. By contrast, a small surface area enables leaves to avoid overheating by remaining closer to the ambient air temperature (Gates, 1968; Dong *et al.,* 2017b).

Clustering analysis separated the leaf traits into populations with a delta K peak value of 2 and stem traits into three populations, with a delta K peak value of 3 showing a high percentage of variability within the chili genotypes. While in the case of the stem length, stem thickness, and stem angle exhibited good variability among the three populations, with CV values of 0.28, 0.22, and 0.15 respectively.

The correlation matrix between characters indicated that stem length and stem angle had a positive correlation with leaf area and size. Such correlations between the vegetative organ of the tree and the size of the fruits were reported for several woody species and underscore the role photosynthetic organ play in increasing fruit size and weight (Primack *et al.,* 1987; Roper *et al.,* 1987; Cornelissen *et al.,* 1999).

5. Conclusion

The study conducted a morphological characterization of chili genotypes in the Republic of Korea and found significant correlations between their vegetative traits (leaf and stem). These correlations can help in the early selection of productive genotypes, and the traits studied have high heritability values and can be used to establish organ descriptors. The study also showed that there was great variability among the studied traits in the chili accessions in the Republic of Korea, and the qualitative traits studied can be used to differentiate between them. The leaf and stem parameters were found to be particularly useful, as improving one character can lead to the improvement of others. The best-performing accessions were observed in almost all provinces, but the choice depends on farmers' objectives and commercial needs.

To enhance our understanding of the phenotypic diversity of chili and improve the conservation, evaluation, and utilization of its germplasm resources, it is necessary to use molecular biology techniques to systematically explore the genetic basis of phenotypic variation among and within natural populations of chili genotypes.

Chapter III. Reproductive organs: Flowers, Fruits

1. Introduction

Each flower has a distinctive color, shape, and scent, and is made up of sepals, petals, pistils, and stamens. The flowers also produce fruit, which means they set seeds. The colors of chili flowers are mainly white or cream, with some purple and red. The color of the chili flower doesn't usually have the same direct impact on consumers as the fruit. However, the color and shape of the flower can provide information about the health of the chili plant, and varieties can be identified by the color, shape, and size of the flower (Byun *et al.,* 2016).

The shape of petals can be analyzed by morphological analysis of flower images using image analysis methods to batch process images and extract quantitative information of flower features. And certain phylogenetic relationships between cultivars can be inferred from the data of flowers constructed by morphological analysis (Chacón *et al.,* 2013). In addition, flower morphology is an important part of determining pollination and fruit shape. Capsicum flowers grown at temperatures below 18°C swell to a much larger diameter than flowers grown at temperatures above that. This change in flower morphology is known to occur at low temperatures, resulting in reduced pollen viability and germination. Identification of flower morphology by image analysis can help determine fruit shape (Aloni *et al.,* 1999).

The fruits of chilies protect the seeds and provide food and nutrition for people. Fruits are produced in a wide range of sizes and shapes, and their characteristics have an important impact on crop yield and external quality (Li *et al.,* 2022). The shape and size of the fruit varies between and within cultivars, with variations in fruit shape, size (length, width) and color (regular, irregular), pericarp thickness (hardness) characteristics, and taste (bitter, sweet) and aroma. The various external characteristics of the fruit affect its production, play an important role and are evaluated as a measure of commodity value (Bo *et al.,* 2015).

The quality of fruits varies depending on the consumer's purpose of use, and there are subjective factors when evaluating quality. Therefore, objectification and standardization of fruit quality can be used to evaluate quality even if each individual has different characteristics (Kim *et al.,* 2016). Objectification and standardization of quality can be achieved through various image analyses, which can be quickly and objectively measured without damaging the fruit, thus obtaining objective fruit data (Martínez-Ispizua *et al.,* 2022).

The objective of this study is to utilize image-based methods to assess the morphological diversity present in the fruit and flower of chili germplasm. The primary goals include phenotypic characterization, correlation analysis of traits, breeding and variety improvement, quality assessment, and conservation efforts. By examining the morphological traits of the fruit and flower, we aim to gain a comprehensive understanding of the morphological diversity within the chili germplasm. Additionally, the study aims to evaluate fruit and flower quality attributes that are important for consumer preference and marketability.

2. Materials and Methods

2.1. Chilies materials

A total of 188 accessions of *Capsicum annuum* were analyzed in this study as described in Chapter II material and methods section. Chili fruits were collected from resources with abundant chili fruit growth from July in 2022 and moved indoors for filming, and chili flowers were collected from resources with flowering from mid-May and filmed directly in the greenhouse with one flower per resource, using a black umbrella to prevent light disturbance.

2.2. Setting camera

The chili fruit was imaged from the front (outside) and cross-section (inside). The same indoor studio was used for the front view of the chili fruit as for the chili leaves, and the lighting was repositioned to minimize chili fruit features and shadows. The camera model was the same as above.

The camera settings were ISO of 100, focal length of 35mm, and exposure time of 1/15. Due to the convex lens of the camera, the center of the camera may appear thicker than the edges, causing data distortion when measuring, so the distortion correction function in the camera was used to prevent this. The background plate was made in blue to match the color of the chili fruit. A blue clay similar to the background color was used on the bottom to level the fruit in the image. The cross-sections of the chilies were scanned at 300 dpi using an Epson Perfection V39 A4 flatbed scanner. For the background, a homemade black background plate was used to ensure that the inside and outside of the chili fruit were scanned clearly. The same 3D panel that was used to scan the chili leaves and trigger legs was used to scan the chili fruit.

Chili flowers were photographed directly in the chili greenhouse to prevent petal discoloration during transportation from the greenhouse to the indoor studio. To avoid distorting the image data due to the changing sunlight and location, a black umbrella was used to block and control strong light. The camera was the same model used to photograph the chili leaves, fruits, and mills. The camera settings were ISO value of 100, focal length of 40mm, and exposure time of 1/50. Due to the convex lens of the camera, the center part of the camera appears thicker than the edge, which may cause data distortion when measuring. To avoid this, the in-camera distortion correction function was used. The background plate was made in-house in black to match the color of the chili flowers. The flower plate was made to keep the petals intact and to keep it horizontal while shooting, so it can be shot alone. Unlike the panels used for the chili leaves, fruits, and mills, the panels for the chili flowers were made with crop name tags, grayscale calibration, and a space to hold the flowers to reduce the hassle when shooting and moving them around.

2.3. Flowers

2.3.1. Object Extraction

Using ImageJ2 (Fiji) software, flowers were extracted by finding the color threshold value of the flowers. The images below are the original and threshold mask images (Fig. 15).

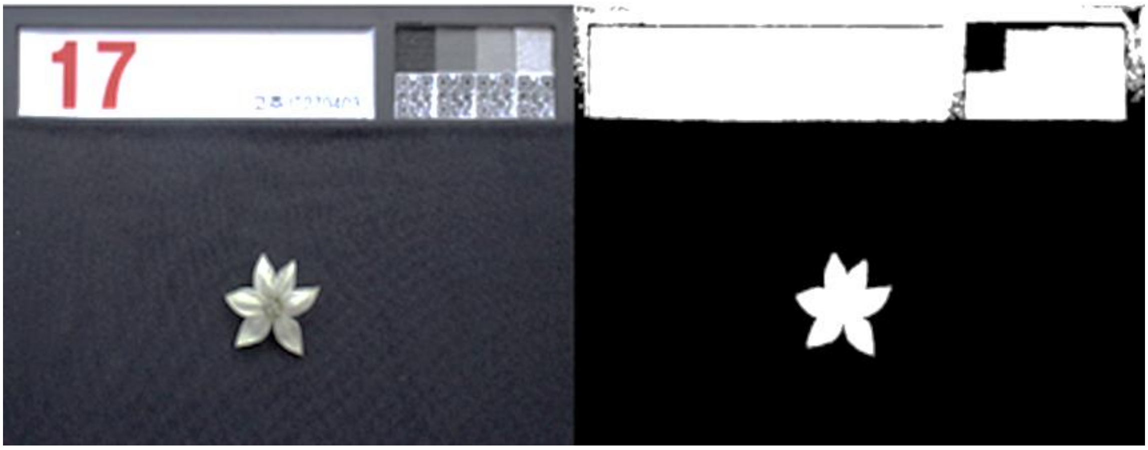


Fig. 15. ImageJ2 (Fiji) software was used for determining the color threshold value of the flower.

2.3.2. Parameter Computation

The parameter we need to find was the area of the flower. First, the width and length of the leaf were calculated through the cv2.FitEllipse() function by calling the OpenCV library of Python. And the area of the leaf was obtained through the cv2.contourArea() function. On the other hand, since these values were in pixels, they must be converted to millimeter. Since we know the reference size through the panel, we can find the scaling factor. Therefore, this value was multiplied to finally obtain all parameter values.

2.4. Fruits

2.4.1. Object Extraction

Fruits were extracted by using ImageJ2 (Fiji) software to find the color threshold value of the fruits. The images below were the original and threshold mask images (Fig. 16).

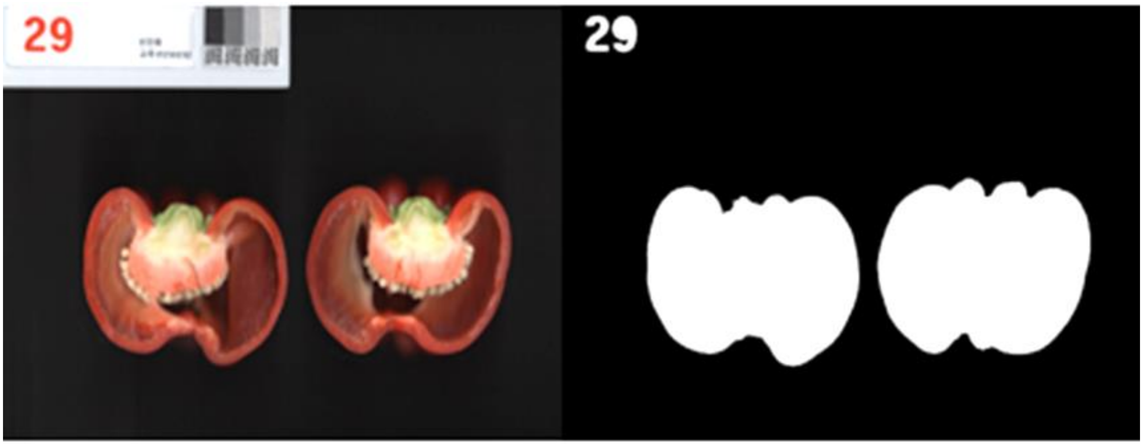


Fig. 16. ImageJ2 (Fiji) software was used for determining the color threshold value of the fruit.

2.4.2. Parameter Computation

The parameters to find were the width, length and area of the fruit. First, the width and length of the leaf were calculated through the cv2.FitEllipse() function by calling the OpenCV library of Python. And the area of the leaf was obtained through the cv2.contourArea() function. On the other hand, since these values were in pixels, they must be converted to mm. Since we know the reference size through the panel, find the scaling factor. Therefore, this value was multiplied to finally obtain all parameter values.

2.5. Statistical analysis

"All statistical analysis was performed by "R" software (Ver. 4.2.2, RStudio Team, R Foundation for Statistical Computing, Boston). The data sets were checked for normality by the Shapiro-Wilk test. The data sets of each trait showed a normal distribution, the parametric One-way ANOVA test followed by the Fisher’s least significant difference (LSD) post hoc test was used to compare measured traits of 188 entries of chili. For correlation analysis was carried out with the Pearson correlation test.

For a more comprehensive description of the results, the K-Mean cluster and principal component analysis (PCA) were used to summarize the relationship among the measure traits. The cluster and PCA plots were generated through the "factoextra" R package".

3. Results

The data indicates that there was significant diversity in the qualitative characteristics such as fruit area, fruit length, fruit width, and thickness. The average fruit area was calculated to be in the range of 95.76 to 159.6 (Mean = 169.76mm^2) square millimeters, with a CV value of 0.79 and SD of 135(LSD= 27.58719). While the average fruit length ranged between 21 to 35 millimeters (LSD= 2.067975) and the average fruit width ranged from 5.4 to 9 millimeters (LSD= 1.371263) Table 6, 7 and Fig. 17.

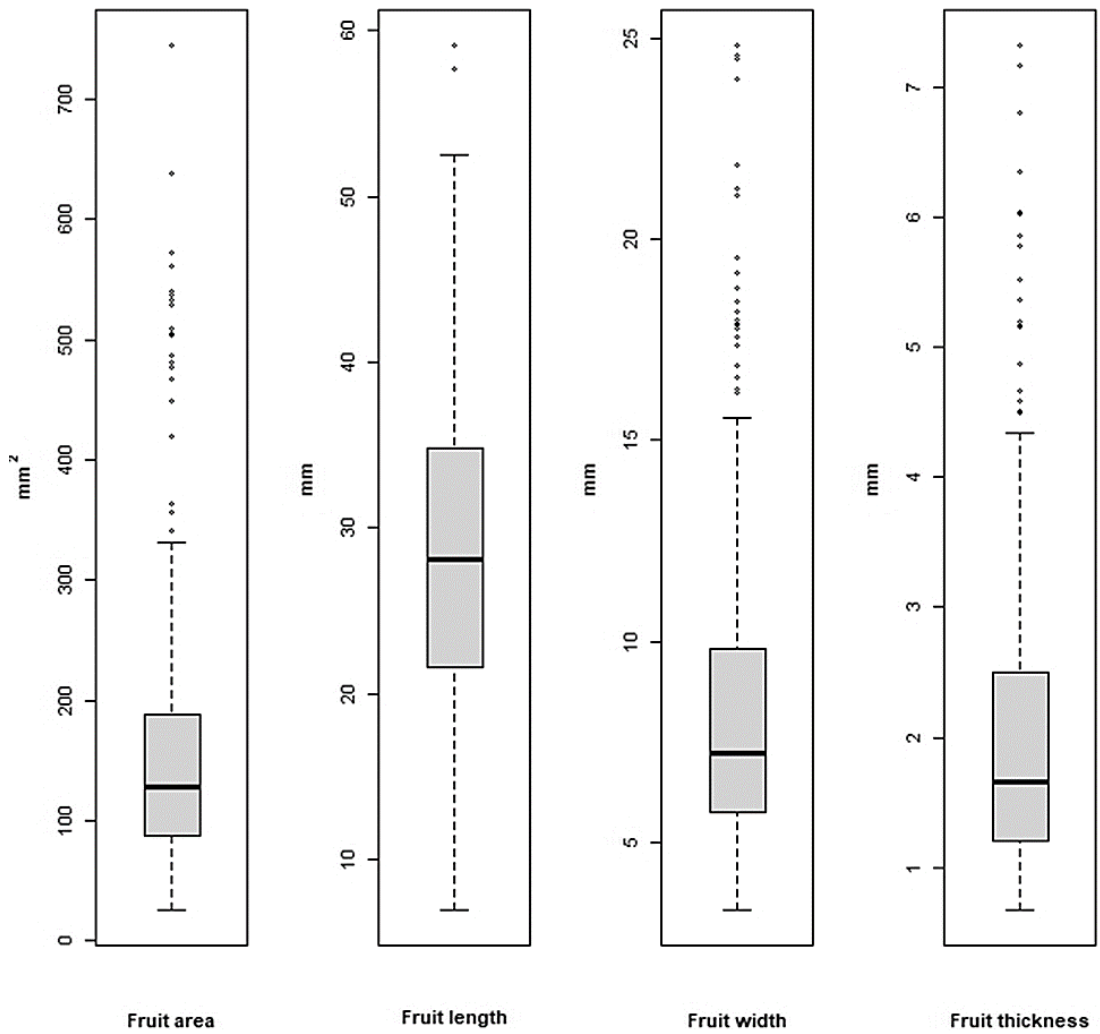


Fig. 17. Box plot showing the average (mean) of fruit traits.

Table 6. The statistical analysis of fruit traits.

Trait	Source	DF	Sum of Squares	Mean Squares	F value	Pr>F		LSD
Fruit area	Rep.	5	4424	885	0.04	0.99	NS	
	Entry	187	20792461	111190	189.4	2.00E-16	***	27.58
Fruit length	Rep.	5	9	1.79	0.01	1	NS	
	Entry	187	112840	603.4	187.1	2.00E-16	***	2.06
Fruit width	Rep.	5	11	2.15	0.09	0.99	NS	
	Entry	187	25091	134.17	84.67	2.00E-16	***	1.37
Fruit thickness	Rep.	5	3.4	0.67	0.32	0.9	NS	
	Entry	187	2256.7	12.06	116.6	2.00E-16	***	0.36

*** Significant at the 0.001 probability level, respectively.

NS = Nonsignificant at $P < 0.05$.

Table 7. The statistical analysis of four fruit traits studied in the 188 genotypes of chili germplasm.

	Fruit.area	Fruit.length	Fruit.width	Fruit.thickness
Min	25.21	6.91	3.3	0.67
Max	745	59.12	24.83	7.32
Mean	169.76	28.02	8.79	2.15
Median	31.92	7.04	1.8	0.41
SD	135.68	9.91	4.7	1.41
CV	0.8	0.35	0.53	0.65

Bivariate analysis indicates a positive correlation between fruit area and fruit length, width, thickness and fruit width and fruit thickness also show positive correlation. A part of them shows a strong positive correlation; area - length, area - width, and area – thickness, also the last part of them indicates a weak positive correlation; length-width, and length-thickness. This means that the two variables tend to increase or decrease together, and they have a clear linear relationship. In our study, there was a strong correlation between the studied traits (Fig. 18).

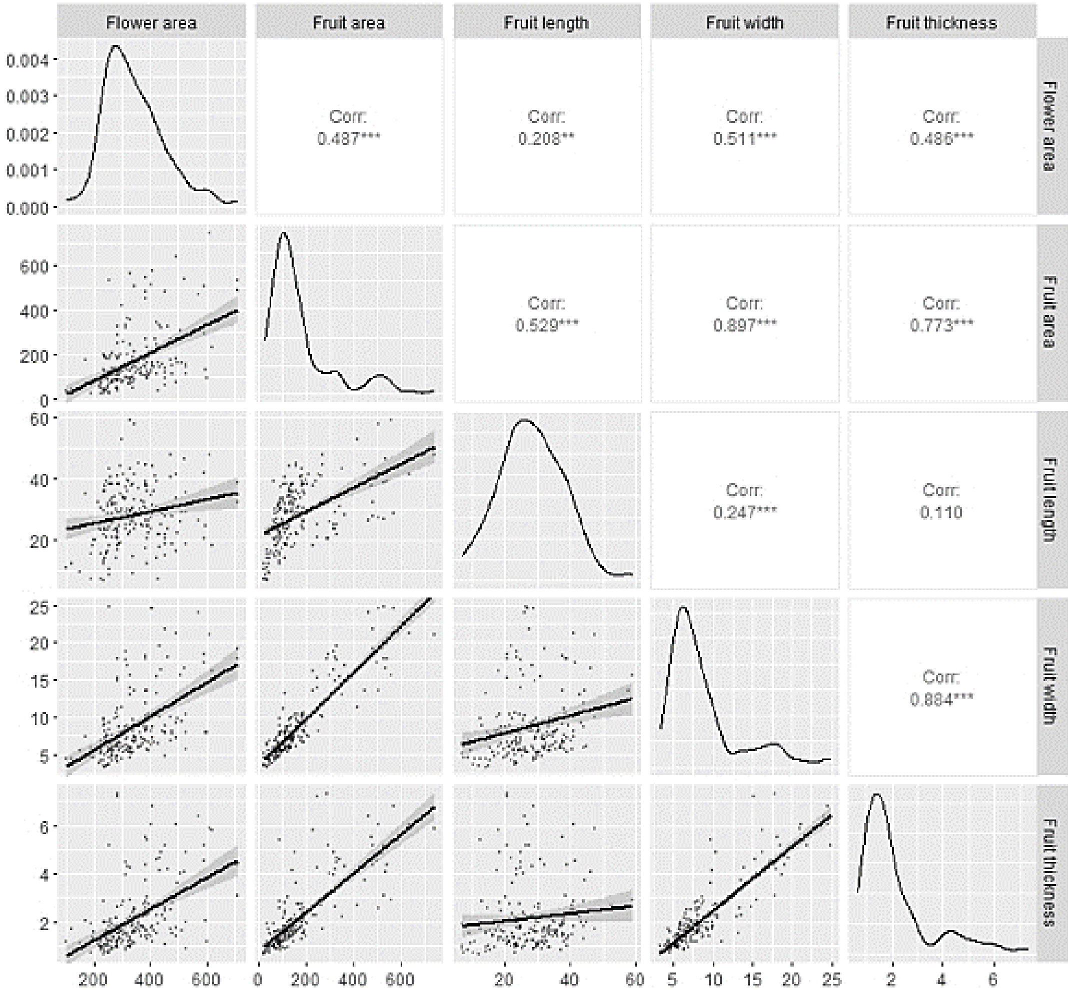


Fig. 18. Bivariate analysis showing the correlation between chili reproductive traits.

** and *** Significant at the 0.01 and 0.001 probability level, respectively.

The study was conducted to determine the degree of variation between the different traits of fruits in chili genotypes and group them based on their similarities. To achieve this, we examined the phenotypic variability among 118 genotypes and used dendrograms to show the phenotypic relationship between the traits. We found significant differences in traits between the different clusters formed. In this analysis of leaf traits in 188 genotypes, two distinct clusters were formed, with clusters one and two consisting of the accessions/genotypes (Fig. 20b). The number of clusters was determined using K pot analysis, and a value of 2 was chosen based on a higher ΔK value (Fig. 19) relative to the number of clusters suggested by R software.

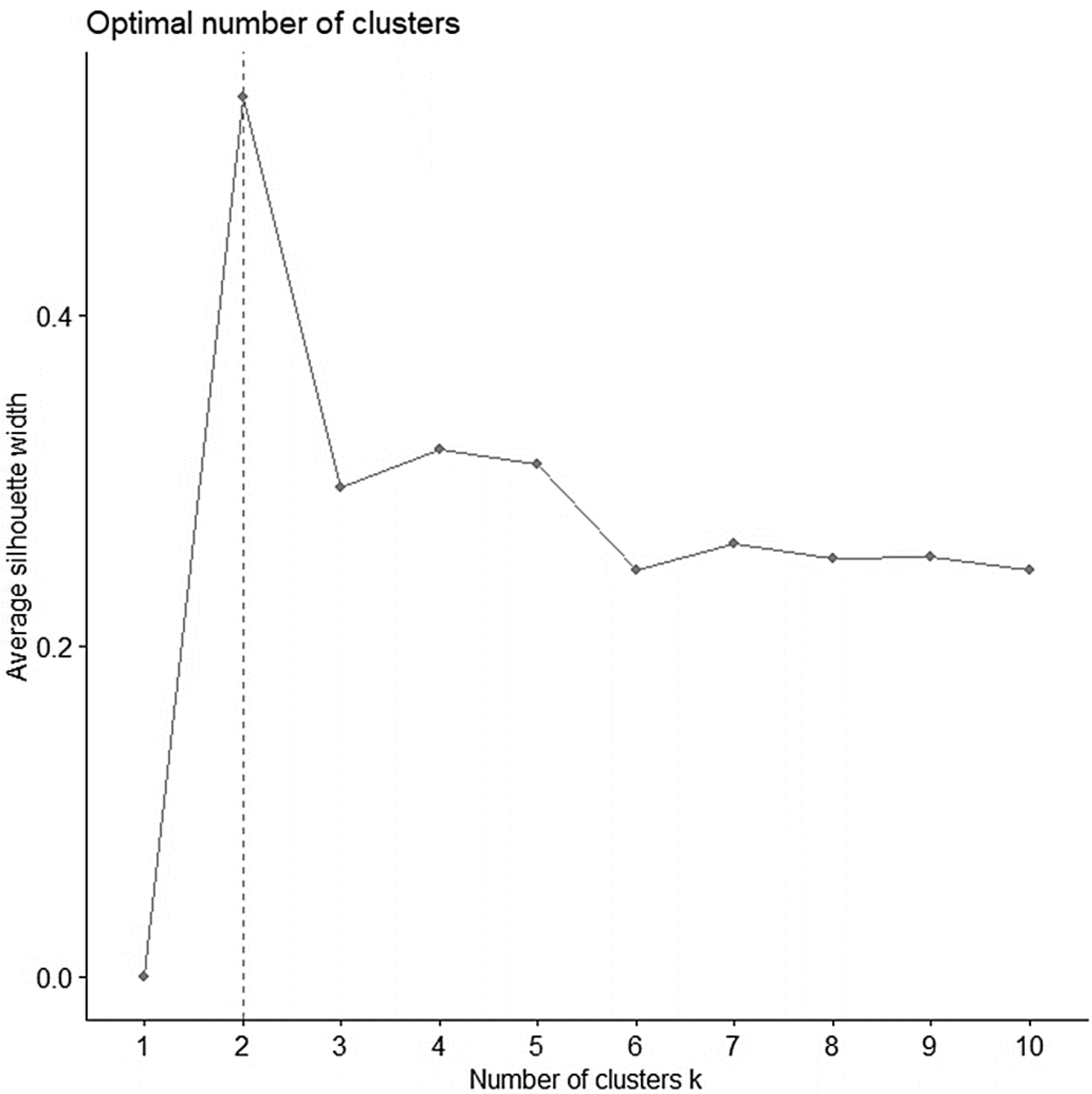


Fig. 19. ΔK peak value of 0.6 among the assumed K showing peak value at 2.

PCA is a statistical method that determines how much each variable contributes to the overall variation along the principal axes. The eigenvalues obtained from PCA are commonly used to select the most discriminating factors among the variables. The sum of all the eigenvalues is usually equal to the total number of variables. For instance, in this analysis, the first principal component explains 2.84 times more variance than the original variables. The two principal components with eigenvalues greater than one account for 64% of the total variation. The results showed that the first two principal components explained 64% and 19.5% of the phenotypic variation (Fig. 20a).

a.

b.

Fruit Cluster

Cluster 1		**Cluster 2**							
IT236351	IT209941	IT113643	IT218753	IT225029	IT236347	IT236413	IT163502	IT223686	IT236471
IT236352	IT223753	IT113703	IT218755	IT228971	IT236348	IT236414	IT163508	IT223692	IT236772
IT236420	IT235610	IT113724	IT218885	IT229664	IT236356	IT236417	IT163534	IT223700	IT236337
IT236433	IT235664	IT158377	IT218895	IT229979	IT236357	IT236423	IT164924	IT223702	IT236345
IT236448	IT235872	IT158433	IT218937	IT231157	IT236360	IT236425	IT171362	IT223706	IT236346
IT236449	IT235874	IT158626	IT219028	IT231165	IT236361	IT236426	IT183648	IT223715	IT236409
IT236451	IT235875	IT158645	IT219847	IT231172	IT236363	IT236427	IT183651	IT223717	IT236410
IT236453	IT235877	IT158647	IT219850	IT231173	IT236364	IT236428	IT183652	IT223718	IT236412
IT236458	IT235878	IT158648	IT221658	IT231179	IT236365	IT236429	IT189942	IT223742	
IT236459	IT235914	IT158651	IT221680	IT231186	IT236366	IT236430	IT208425	IT223755	
IT236460	IT235915	IT158669	IT221876	IT231187	IT236367	IT236431	IT213251	IT223777	
IT236532	IT236255	IT158846	IT221877	IT231393	IT236371	IT236432	IT218726	IT223780	
IT236755		IT158850	IT221884	IT235611	IT236373	IT236434	IT235870	IT236395	
IT236273		IT158859	IT221900	IT235612	IT236374	IT236435	IT235921	IT236396	
IT236293		IT158873	IT221901	IT235613	IT236377	IT236436	IT236215	IT236397	
IT236312		IT158876	IT221904	IT235614	IT236385	IT236465	IT236288	IT236400	
IT236339		IT158893	IT221909	IT235615	IT236386	IT236466	IT236295	IT236401	
IT236343		IT158894	IT221910	IT235616	IT236387	IT236467	IT236313	IT236402	
IT236349		IT158895	IT221913	IT235618	IT236390	IT236468	IT236333	IT236403	
IT236350		IT163495	IT221914	IT235661	IT236392	IT236469	IT236334	IT236405	
IT236272		IT163500	IT223683	IT235865	IT236394	IT236470	IT236336	IT236408	

Fig. 20. Dendrograms showing distribution of chili germplasm into 2 clusters based on fruits traits (a), Represents the fruit cluster distribution of accessions (b).

Flower traits

The data indicates that there was also significant diversity in the qualitative characteristics such as flower area. The average flower area was calculated to be in the range of 241-to-401-millimeter squares (Mean = 341mm^2), with a CV of 0.311 and an SD of 106.

Flower and fruit traits

The PCA and clustering analysis conducted between the fruit and flower traits showed a strong correlation between fruit thickness and fruit width with the flower area as compared with the fruit area and length. The results showed that the first two principal components explained 64% and 19.5 % of the phenotypic variation (Fig. 21).

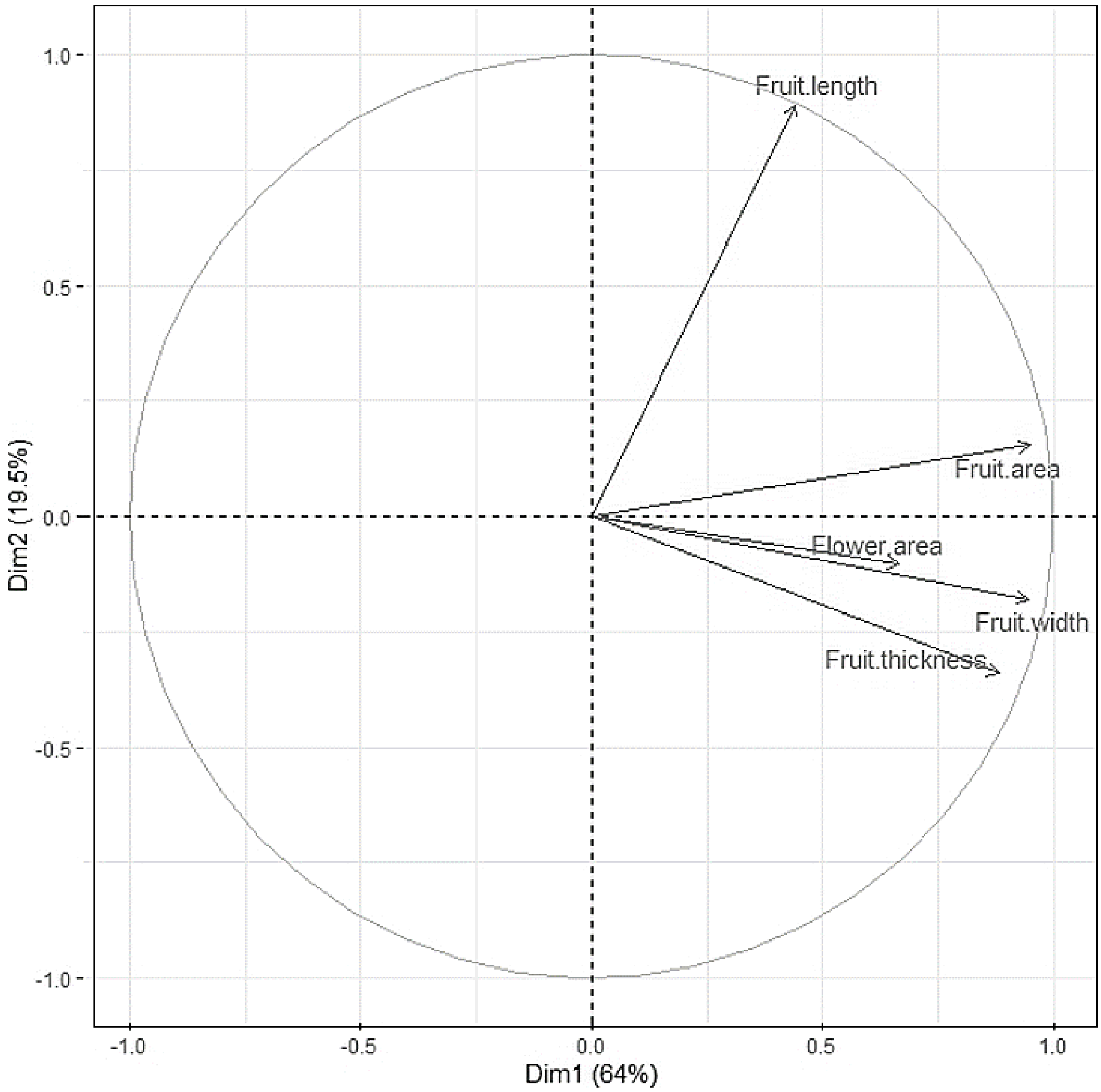


Fig. 21. Principal coordinate analysis showing the distribution of reproductive organ traits into 2 coordinates.

4. Discussion

Chili *(Capsicum spp.)* is a crop in which the fruit's shape and color are crucial factors for defining market types and are therefore significant targets for varietal selection. Consequently, improving fruit morphology and color are major goals for breeding programs in this crop. This research aims to address the absence of extensive phenotyping studies in chili by conducting a comprehensive evaluation of a diverse collection of chili accessions. This study represents the initial effort to thoroughly examine a broad range of accessions in terms of both their number and diversity. The study began by examining the phenotypic variations among different species within the collection.

Phenotypic diversity is influenced by genetic and environmental factors and their interactions (Zhigila *et al*., 2014). Phenotyping of desirable traits is the simplest and most direct way to investigate and assess the diversity of chili germplasm resources, which is crucial for rational conservation and genetic improvement (Chen *et al*., 2018). Understanding the genetic and phenotypic composition of populations and investigating their genetic and phenotypic variability is very essential for efficient management of chili genetic resources (Silva *et al.,* 2016; Li *et al.,* 2022).

In this study, a comprehensive evaluation of variation in four phenotypic traits of fruit among 188 genotypes was carried out. The study further investigated the association between these traits and factors influencing phenotypic variation. While Amzad *et al*. reported that greater fruit width was associated with greater fruit area. Also, our study showed a strong positive correlation between greater fruit width and greater thickness, and a strong positive correlation between greater petal area and greater fruit area (Amzad Hossain *et al.,* 2003).

In this study, the coefficient of variation (CV) was used to evaluate the level of variation in germplasm for each trait. The results showed that fruit area, fruit length, fruit, width, and fruit thickness had CV values of 0.80, 0.35, 0.53, and 0.65, respectively, indicating good variability between two groups (clusters). Capsicum fruits are of paramount economic importance to producers and consumers and are indispensable for the survival and evolution of the next generation. The average CV of fruit traits in chili germplasm was quite high, indicating that fruit traits were vulnerable to environmental factors; however, this could also be partly due to differences in genetic background among the studied genotypes. Overall, the high variability observed in leaf traits emphasizes their importance in the evaluation and conservation of plant germplasm resources.

The coefficient of phenotypic differentiation is a measure of how much traits in species differ, with a higher coefficient indicating a greater potential for population differentiation. Temperature determines the amount of carbohydrates transferred to the flower, which in turn determines the size of the fruit (Aloni *et al*., 1999; Link, 2000). These different environments can cause plants to vary in size and shape.

Cluster analysis showed that the fruit traits were clustered with a delta K peak value of 2, indicating high variability within chili genotypes, while flower area had a CV value of 0.31.

The correlation matrix between characters indicated that fruit area, fruit width, and fruit thickness were positively correlated with flower area, while fruit length was marginally correlated. These correlations highlight the importance of chili production, its multiple uses, and the role that producers, consumers, and other users can play in expressing and maintaining it.

The current approach is used for characterizing the phenotypic basis of fruit shape (Width, area, length, and thickness) along with flower area in chilies for the potential to yield more insights. So far, different types of research have been conducted using various bi-parental intra- and interspecific mapping populations, which have identified various QTLs with minor or major effects. However, these mapping populations have limitations, as they only capture the variation of the two parents and can be affected by a lack of recombination during interspecific hybridization. By implementing high-throughput phenotyping in association studies on large collections of chilies, researchers can explore the existing variation and gain a better understanding of the genetic basis of fruit morphology traits. Additionally, morphological traits can provide useful information in assembling core collections and identifying suitable parent plants for use in breeding programs (Lefebvre *et al*., 1998; Balakrishnan *et al*., 2000; Ben *et al*., 2003; Zygier *et al*., 2005; Barchi *et al*., 2009; Borovsky *et al*., 2011; Yarnes *et al*., 2013; Han *et al*., 2016).

5. Conclusion

This study performed morphological characterization of chili genotypes in the Republic of Korea and found significant correlations between plant traits (fruit and flower). These correlations can help in the early selection of highly productive genotypes, and the studied traits are highly heritable and can be used to establish these traits. This study also showed that the variation in Korea's chili lines is very large, and the studied qualitative traits can be used to distinguish lines. Fruit and flower traits were found to be particularly useful because improving certain traits can also improve other traits. This diversity can structure the breeding diversity of chili and depends on the farmer's goals and commercial needs.

To improve our understanding of the genetic diversity of chili and to improve the conservation, evaluation, and utilization of chili germplasm resources, there is a need to systematically explore the genetic basis of phenotypic variation among and within natural populations of chili genotypes using molecular biology techniques. Such information is critical for genetic diversity research, conservation, evaluation, and utilization of chili germplasm resources.

In addition to studying the physical traits of chilies, it was examined that there is a relationship between different types of chilies and found similarities among those within the same species. This research has shown that domestication and selective breeding have played a role in expanding the variety of fruit characteristics. This new information will be useful in further understanding the genetic factors that determine fruit traits, which is a key focus in chili breeding. Using high-throughput phenotyping in genome-wide association studies can help to investigate the range of genetic variation in large collections of chilies and provide new insights into the genetic as well as phenotypic basis of fruit morphology traits. Additionally, analyzing morphological traits can help to confirm genetic data and identify suitable parent plants for use in breeding programs when assembling core collections.

Chapter IV. Vegetative organs and Reproductive organs

1. Introduction

A vegetative organ refers to a plant organ that is responsible for the plant's nutrition. Vegetative organs in plants are responsible for nutrition and maintenance, excluding reproductive organs. Stems and leaves serve as vital nutritional organs, performing photosynthesis to produce nutrients and support plant survival and growth (Hong *et al*., 1997; Brazel *et al*., 2019). Leaves also influence environmental factors such as solar radiation, humidity, temperature, and water status. Extensive research has focused on leaves due to their significance in plant biology (Hong *et al*., 1997; Box, 2012; Brazel *et al*., 2019). Leaf size and structure impact photosynthesis and respiration, with size correlating to photosynthetic uptake and structure providing insights into physiological activity (Box, 2012). Traditional leaf measurements using rulers and calipers limited data to length, width, and thickness, but modern imaging techniques enable quantification of parameters like area, color, texture, perimeter, curvature, thickness, and shape (Gelbukh *et al*., 2006; Tak *et al*., 2007; Granier *et al*., 2009; Nakayama *et al*., 2017; Zhuang *et al*., 2020).

Stems are an integral part of the shoot system in plants and exhibit a wide range of lengths, varying from a few millimeters to several meters. Their diameter also differs depending on the plant species. While most stems are found above ground, certain plants, like potatoes, possess underground stems. Stems can be either herbaceous, meaning they are soft and flexible, or woody, characterized by their hardness and durability. The primary role of stems is to provide support to the plant by holding leaves, flowers, and buds. In some cases, stems also serve as storage organs for food reserves. They can have a simple, unstemmed structure seen in palm trees or highly stemmed configurations observed in magnolia trees. The stem acts as a vital link between the plant's roots and leaves, facilitating the transport of water and minerals absorbed by the roots to different plant parts. Furthermore, the stem aids in the distribution of the products of photosynthesis, such as sugars, from the leaves to other areas of the plant (Kang, 2006, Wilson *et al*., 1995; Burgess *et al*., 2006). The length and diameter of the stem determine the plant's growth rate and yield. Longer stems position the leaves to receive light more effectively, resulting in improved photosynthesis. Conversely, shorter stems provide a more reliable water supply, promoting stability in water absorption. Moreover, the width and thickness of the stem influence the plant's yield. Increased stem length and thickness in potatoes, for instance, lead to a proportional increase in the number of fruits produced (Vos *et al*., 1992, Burgess *et al*., 2006). The height and width of the stem are also associated with the duration of plant growth and can affect resistance against lodging, a phenomenon where plants bend or collapse under adverse environmental conditions (Shen *et al*., 2018).

The reproductive system of a plant is responsible for processes like pollination and fertilization, which lead to the formation of seeds and fruits. These seeds and fruits play a crucial role in the plant's reproduction and the survival of the species. In plants, the flowers and fruits are the reproductive organs. Flowers have unique characteristics such as color, shape, and scent. They are composed of several parts, including sepals, petals, pistils, and stamens. These parts work together to facilitate the pollination process, where pollen grains are transferred from the male reproductive organs (stamens) to the female reproductive organs (pistils). Successful pollination leads to fertilization, where the male gametes from the pollen combine with the female gametes in the ovules, resulting in the development of seeds. Fruits, which develop from the fertilized flowers, enclose and protect the seeds. They play a vital role in seed dispersal, allowing plants to spread their offspring to new areas. Fruits can have different forms and functions, ranging from fleshy fruits like apples or berries to dry fruits like nuts or capsules. The timing of flowering is critical for plant reproduction. In temperate climates, plants have evolved a mechanism called vernalization to ensure that they flower during favorable conditions, typically in spring or summer. Vernalization involves the perception and response to extended periods of cold during winter. This process enhances the plant's ability to transition from vegetative growth to the flowering stage, increasing the chances of successful reproduction. However, early flowering can be disadvantageous in some plant species. In crops such as cabbage, sugar beet, or fodder grasses, early bolting (premature flowering) can negatively impact potential yield improvements or disrupt harvest operations. Similarly, in trees and perennial plants, delayed flowering can pose challenges for breeding advancements. The delayed onset of flowering in these plants hinders efforts to breed new varieties or make improvements in their reproductive traits. (Byun *et al*., 2016, Chacón *et al*., 2013, Aloni *et al*., 1999, Li *et al*., 2022, Bo *et al*., 2015, Kim *et al*., 2016).

Image analysis techniques provide a means to objectify and standardize the quality of fruits by enabling quick and objective measurements of various fruit characteristics. These techniques allow researchers to gather quantitative data about fruit attributes without causing any harm to the fruit. By obtaining objective fruit data, researchers can obtain accurate information about the quality and traits of different fruits, contributing to the standardization of fruit quality.

A study conducted by Martínez-Ispizua *et al*. in 2022 highlights the use of image analysis to achieve objectification and standardization of fruit quality. The researchers employed image analysis techniques to measure and analyze various parameters of fruits without physically altering or harming them. This approach enables the collection of objective data, which can be used to assess the quality and characteristics of fruits accurately.

In another study by Nankar *et al*. in 2020, the researchers utilized a specific software tool called "Tomato Analyzer" to measure the phenotypes of chili fruits. The Tomato Analyzer is a computer-based image analysis tool that allows for the extraction of various fruit traits and characteristics from digital images. By analyzing the fruit phenotypes using this tool, they were able to explore and understand the diversity of fruit traits within chili varieties. The data obtained through image analysis of fruit phenotypes provides valuable information for studying the phenotype and genetics of fruit varieties. Researchers can identify and quantify specific traits such as size, shape, color, texture, and other characteristics that contribute to fruit quality. This data helps in understanding the genetic basis of these traits and enables the comparison and classification of different fruit varieties based on their phenotypic characteristics.

2. Statistical analysis

Statistical analysis was performed using R software (Ver. 4.2.2, R Foundation for Statistical Computing, Boston). Normality of the data sets was checked using the Shapiro-Wilk test. The data sets exhibited a normal distribution. Parametric One-way ANOVA followed by Fisher's LSD post hoc test was used to compare measured traits of 188 chili entries. Correlation analysis was conducted using the Pearson correlation test. To summarize the relationship among the measured traits, K-Mean clustering and principal component analysis (PCA) were employed. Cluster and PCA plots were generated using the "factoextra" R package. All the raw data is given in APPENDIX-II.

3. Results

While performing the analysis on vegetative organs and reproductive organs, the different traits showed a high degree of variance and their distribution pattern also vary as shown in the box plot (Fig. 22)

Bivariate analysis showed a positive correlation among fruit area and flower area, fruit length and fruit area, fruit width, and fruit leaf width. The correlation matrix is attached in Fig. 23. This showed that the fruit size was also depending on the flower as well as leaf area which in turn is depending upon the rate of photosynthesis.

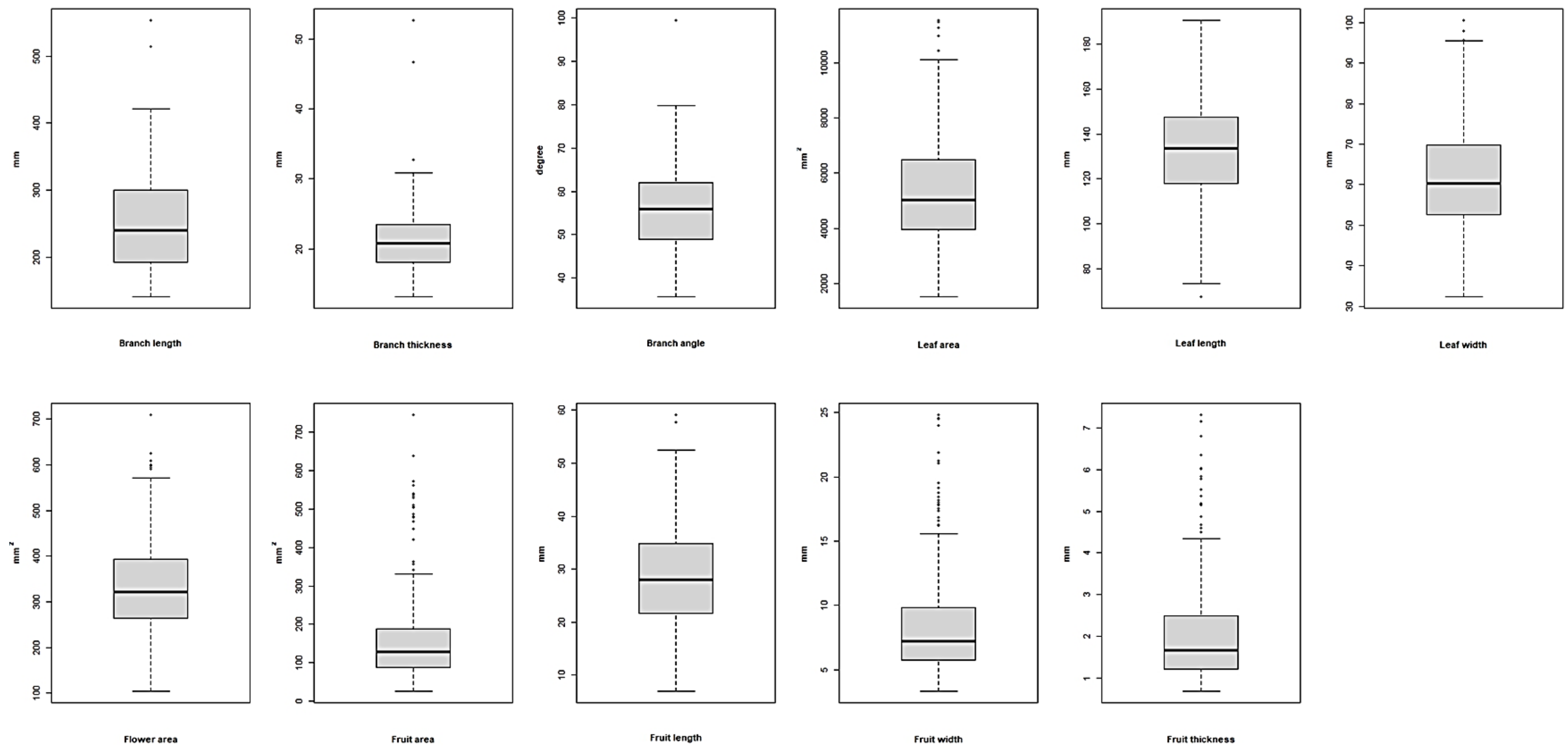


Fig. 22. Box plot showing the average (mean) of all traits combined (Leaf, stem, flower and fruit) traits.

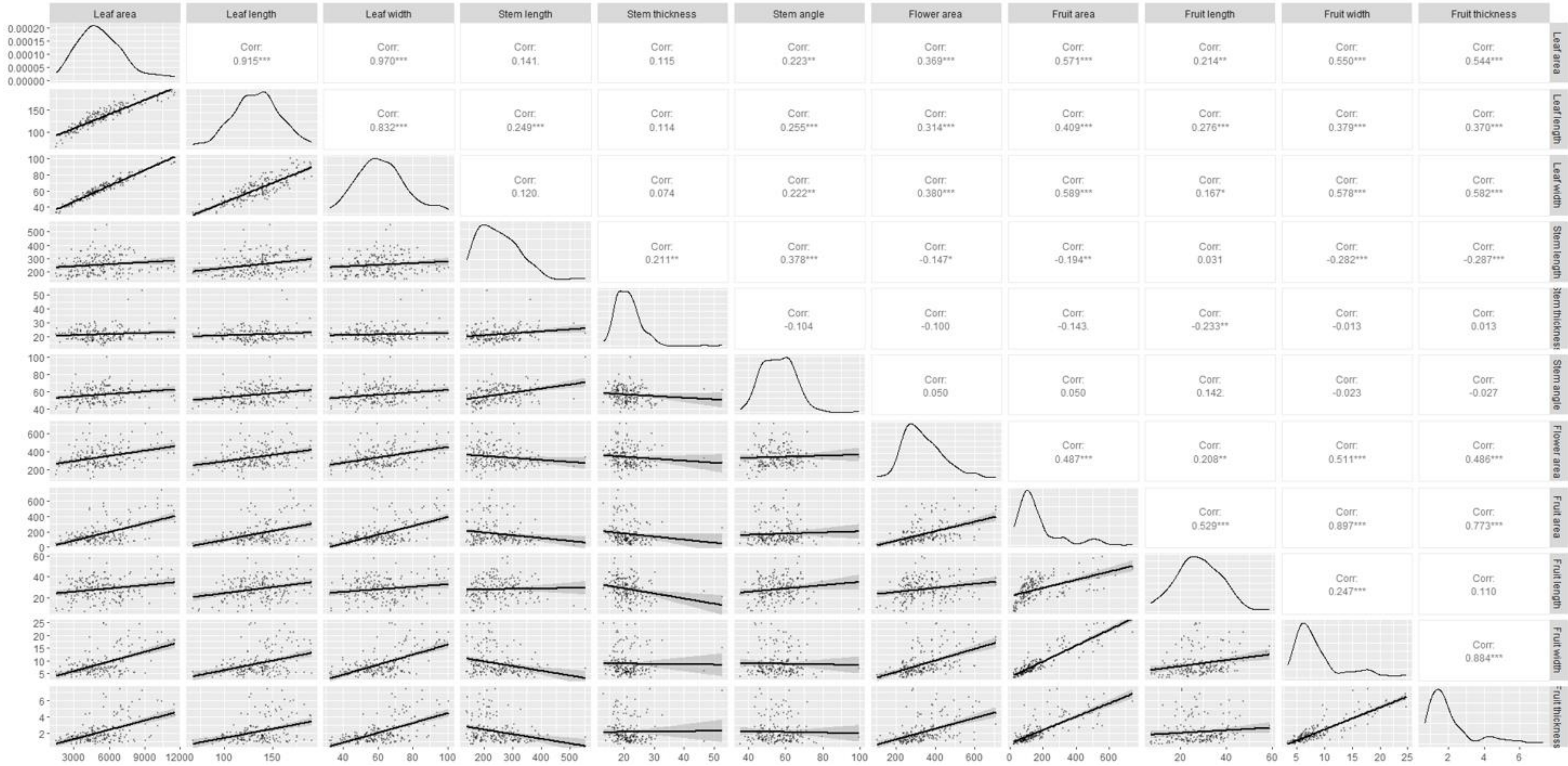


Fig. 23. Bivariate analysis showing the correlation between different chili traits (leaf, stem, flower and fruit).

*, ** and *** Significant at the 0.1, 0.01 and 0.001 probability level, respectively.

The number of clusters was determined using K pot analysis, and a value of 2 was chosen based on a higher ΔK value relative to the number of clusters suggested by R software (Fig. 24). To determine the degree of variation between vegetative and reproductive traits two distinct clusters were formed, one representing the vegetative traits and another reproductive trait (Fig. 25a and 25b).

While performing PCA the fruit variables fall in one coordinate and show a strong co-relationship with the flower area. The leaf traits had a strong correlation among the traits but the stem traits are not positively correlated with fruit traits. PCA is a statistical method that determines how much each variable contributes to the overall variation along the principal axes. The eigenvalues obtained from PCA are commonly used to select the most discriminating factors among the variables. The sum of all the eigenvalues is usually equal to the total number of variables. For instance, in this analysis, the first principal component explains 4.74 times more variance than the original variables. The results showed that the first two principal components explained 43.1% and 18.1% of the phenotypic variation (Fig. 26).

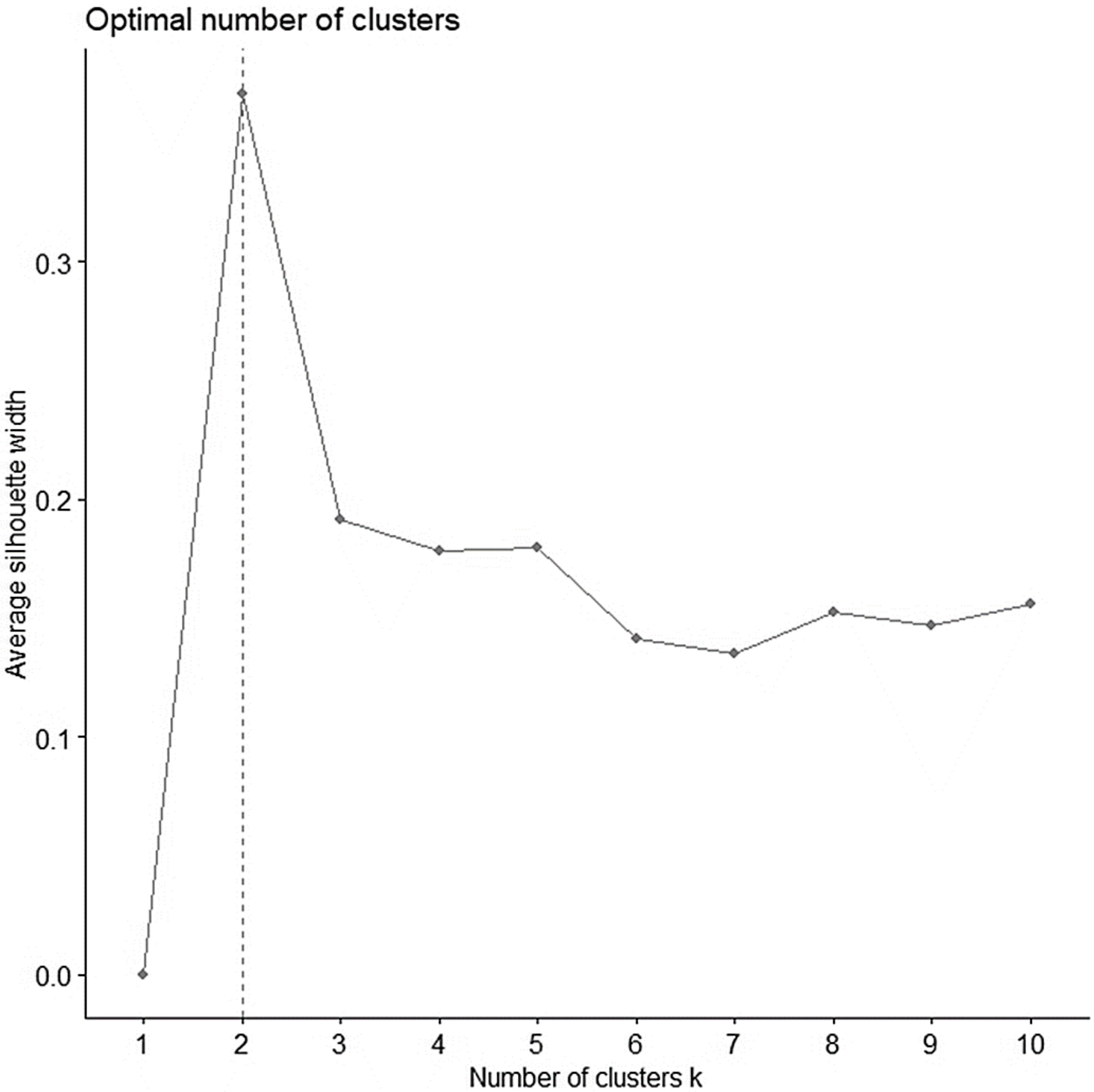
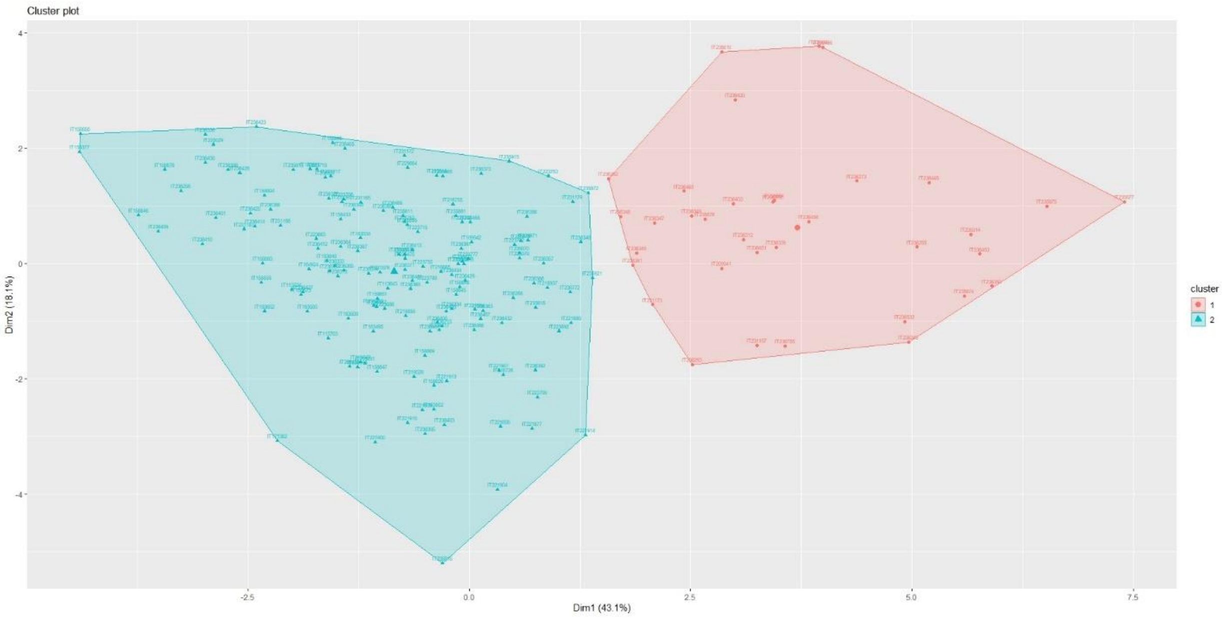


Fig. 24. ΔK peak value of 0.35 among the assumed K showing peak value at 2 (means 2 cluster formation) among different traits (leaf, stem, flower, and fruit).

a.



b.

All organs Cluster

Cluster 1		Cluster 2								
IT236339	IT209941	IT113643	IT218885	IT229979	IT236365	IT236431	IT158895	IT223683	IT235915	IT236402
IT236343	IT231157	IT113703	IT218895	IT231165	IT236366	IT236432	IT163495	IT223686	IT235921	IT236403
IT236345	IT231173	IT113724	IT218937	IT231172	IT236367	IT236434	IT163500	IT223692	IT236215	IT236405
IT236347	IT235610	IT158377	IT219028	IT231179	IT236371	IT236435	IT163502	IT223700	IT236288	IT236408
IT236348	IT235664	IT158433	IT219847	IT231186	IT236373	IT236436	IT163508	IT223702	IT236295	IT236409
IT236349	IT235874	IT158626	IT219850	IT231187	IT236374	IT236465	IT163534	IT223706	IT236313	IT236410
IT236350	IT235875	IT158645	IT221658	IT231393	IT236377	IT236466	IT164924	IT223715	IT236333	IT236412
IT236351	IT235877	IT158647	IT221680	IT235611	IT236385	IT236467	IT171362	IT223717	IT236334	IT236413
IT236352	IT235878	IT158648	IT221876	IT235612	IT236386	IT236468	IT183648	IT223718	IT236336	IT236414
IT236420	IT235914	IT158651	IT221877	IT235613	IT236387	IT236469	IT183651	IT223742	IT236337	
IT236433	IT236255	IT158669	IT221884	IT235614	IT236390	IT236470	IT183652	IT223753	IT236346	
IT236448	IT236272	IT158846	IT221900	IT235615	IT236392	IT236471	IT189942	IT223755	IT236356	
IT236449	IT236273	IT158850	IT221901	IT235616	IT236394	IT236772	IT208425	IT223777	IT236357	
IT236451	IT236293	IT158859	IT221904	IT235618	IT236395	IT236427	IT213251	IT223780	IT236360	
IT236453	IT236312	IT158873	IT221909	IT235661	IT236396	IT236428	IT218726	IT225029	IT236361	
IT236458	IT236460	IT158876	IT221910	IT235865	IT236397	IT236429	IT218753	IT228971	IT236363	
IT236459	IT236532	IT158893	IT221913	IT235870	IT236400	IT236430	IT218755	IT229664	IT236364	
IT236755		IT158894	IT221914	IT235872	IT236401	IT236426	IT236425	IT236423	IT236417	

Fig. 25. Dendrograms showing distribution of chili germplasm into 2 clusters based on leaf traits (a), Represents the all organs traits cluster distribution of accessions (b).

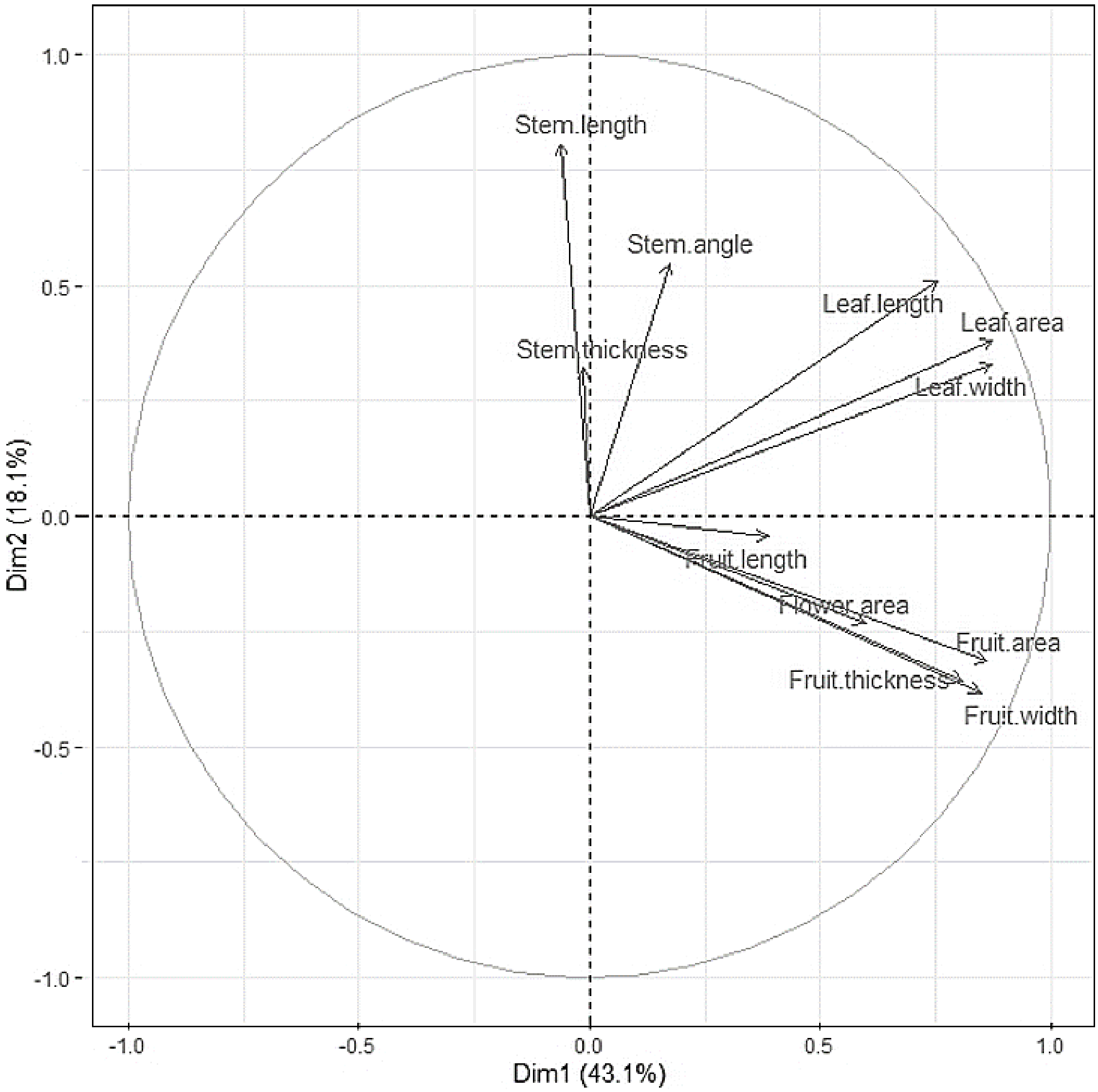


Fig. 26. Principal coordinate analysis showing the distribution of all traits (leaf, stem, flower and fruit) into different coordinates.

4. Discussion

Photosynthesis plays a crucial role in the growth and development of plants. When photosynthesis is insufficient, it can cause an increase in defoliation and drop rates, ultimately leading to lower yields. This highlights the close relationship between the nutritional and reproductive systems in plants. Photosynthesis is an essential process in the nutritional system, and the products derived from it are necessary for the development and functioning of the reproductive system. This close interdependence between these systems emphasizes the critical role that photosynthesis plays in the overall growth and productivity of plants (Ioslovich *et al.,* 2005; Kim *et al.,* 2011).

The size of fruits and the number of stems can vary depending on various factors, such as the amount of light intake and respiration rate. An increase in the number of stems can lead to an increase in the number of leaves and fruits. This, in turn, requires a higher level of assimilation from nutrient growth organs and fruits. This could lead to competition between the fruits and nutrient organs for these assimilates. Therefore, there can be significant competition among different parts of the plant for resources, affecting the final yield and overall growth (Yoon *et al.,* 2021)

The study found a significant correlation between three important traits - Flower area, fruit thickness, and fruit area - which are crucial in describing the characteristics of a breed. This suggested that these traits were closely related and could be used as indicators to predict the performance of the breed in terms of flower and fruit quality. Further research could explore the underlying mechanisms that drive this correlation and identify ways to enhance these traits in breeding programs. By the size and shape of the flowers and the size of the leaves, species can be classified and the size of the fruit can be predicted. (Primack *et al.,* 1987; Rosati *et al.,* 2010; An *et al.,* 2022).

The relationship between flower area, fruit thickness, and fruit area can differ based on various environmental factors and specific plant species. Our research indicated that there was a positive correlation between flower area and fruit area, indicating that larger flowers may result in larger fruits due to their potential to attract more pollinators and increase fertilization rates. Additionally, a positive correlation exists between fruit thickness and fruit area, where thicker fruit walls may provide better support and protection for the developing seeds, allowing them to grow larger. However, there may not be a strong correlation between flower area and fruit thickness as thicker fruit walls can depend more on genetics, environmental factors like water availability and temperature, and the specific plant species. According to Donskih *et al.* (2022) the length of the filament had a strong relationship with the length of the fruit (r= -0.71) and the leaf's length (r=-0.71), also it was closely related to all leaf traits with a positive relationship.

There was no significant correlation between the stem angle, thickness, and length with fruit size or area. Also, no significant correlation was found between stem traits and flower traits. The stems can affect the transport of water and nutrients to the fruit. Thicker stems tend to have a higher capacity for transporting water and nutrients, which may enhance fruit development and quality. But no such correlation or results have been found.

Leaf area growth is a key factor that determines a crop's ability to intercept light, and is frequently used as an indicator of plant growth in high-throughput phenotyping system. The amount of leaf area a plant produces is a crucial factor in determining its productivity because it directly affects the amount of light it can absorb. Plants with a high net rate of photosynthesis, combined with the ability to produce large amounts of leaf area over an extended period of time, tend to have high biomass production (Barigah *et al.,* 1994; Weraduwage *et al.,* 2015).

Our study showed that there was a strong correlation between leaf area, leaf width, and leaf length with flowering and fruit production in chili genotypes. Larger leaf area could result in higher photosynthetic rates, leading to increased carbohydrate production and ultimately, better flower and fruit development. Similarly, wider and longer leaves could provide more surface area for photosynthesis, which can enhance plant growth and reproductive success.

Furthermore, the timing of flowering and fruit production could also be influenced by leaf characteristics. For instance, leaves that are broader and longer may delay the onset of flowering due to higher investment in vegetative growth. Conversely, smaller leaves with a smaller surface area may induce earlier flowering and fruiting as the plant invests more resources in reproduction rather than growth.

The findings offered strong evidence, rooted in evolutionary relationships, that there was a close correlation between the size of a flower and the number of fruit it produces. Additionally, certain combinations of traits, such as small flowers with few seeds or large flowers with many seeds, have been present in monocotyledons for a longer time than other trait combinations. Furthermore, changes in reproductive traits are often accompanied by changes in vegetative traits (Bawa *et al.,* 2019).

5. Conclusion

Understanding how leaf characteristics influence the development of flowers and fruits can have significant implications for plant breeding and crop management. By selecting plants with desired leaf traits, breeders can indirectly select for improved flowering and fruiting traits. Furthermore, optimizing leaf characteristics through proper nutrition, water management, and other cultural practices can promote more efficient photosynthesis, leading to better yield and quality of fruit.

With the help of high-throughput phenotyping platforms, breeders will be able to identify new traits associated with flower, fruit, and leaf development in chili, which can help develop improved chili cultivars with desired traits such as increased yield, enhanced nutritional content, improved resistance to pests and diseases, and better adaptation to changing environmental conditions. As sustainable and environmentally friendly farming practices gain importance, breeding programs will increasingly focus on developing crops with improved photosynthetic and nutrient-use efficiency, making such traits even more valuable.

In summary, the future of flower, fruit, and leaf traits in chili and other breeding programs looks promising. With the help of advanced technologies and a more profound comprehension of the genetic and physiological mechanisms governing these traits, breeders will have better tools to develop crops that fulfill the growing expectations of consumers and producers.

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Morphological Diversity Analysis of *Capsicum annuum* Using an Image-Based Method for Crop Improvement

박지은

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고추는 풍미와 영양의 원천을 포함하여 다양한 용도로 사용되는 작물로서, 유전적 다양성을 분석하여 새로운 품종 개발이 필요하다. 바람직한 형질을 가진 새로운 품종을 개발하기 위해 고추 생식세포의 유전적 다양한 분석이 중요하다. 기존의 분석 방법은 시간과 노동 집약적일 수 있다. 따라서 본 연구는 이미지 기반 방법을 사용하여 고추 생식세포의 형태적 다양성을 분석함으로써 작물 육종과 생산을 개선하는 것을 목표로 한다.

연구방법은 다음과 같다. 본 연구는 36 개국에서 수집한 188 개의 고추 계통을 분석하였으며, 각 계통의 지리적 원산지 데이터는 국립종자원에서 확보하였다. 연구 분석은 잎의 너비, 길이, 면적, 가지의 각도, 길이, 두께, 열매의 면적, 길이, 너비, 두께와의 상관관계에 초점을 맞췄으며, 추가로 꽃의 면적과 열매 형질 간의 상관관계를 분석하였다.

연구 결과, 잎의 면적, 잎의 길이, 잎의 폭은 두 집단(K=2) 간에 각각 0.38, 0.179, 0.22 의 CV 값으로 유의미한 변동성이 있는 것으로 나타났다. 평균 잎의

면적은 5,317mm2, 평균 잎의 길이는 100~166mm, 평균 잎의 폭은 45~75mm 범위였으며, 평균 가지의 길이는 180~301mm, 두께는 15~26mm 범위를 보였다. 또한 평균 열매의 면적은 169.76mm2 이고 CV 값은 0.79 로 나타났으며, 평균 열매의 길이는 21~35mm, 평균 열매의 너비는 5.4~9mm 범위였다. 이로서 꽃 면적과 같은 질적 특성에서도 상당한 다양성을 확인 하였다.

또한 잎의 면적, 너비, 길이가 고추 유전자형에서 개화 및 과실 생산과 밀접한 상관관계가 있는 것으로 나타났다. PCA 는 잎, 가지, 열매, 꽃 특성 간에 43.09%와 18.1%의 변이를 보였다. 가지 형질에 비해 잎, 열매, 꽃 형질 간에 강한 상관관계가 나타났다. 이로서 꽃 면적, 과실 두께, 과실 면적 등 세 가지 특성이 품종을 설명하는 데 중요한 것으로 확인되었다.

결과적으로 본 연구는 육종 프로그램의 발전에 기여하여 소비자와 생산자의 요구 사항을 충족하는 개량된 고추 품종을 개발할 수 있음을 밝혔다. 본 연구로 인해 육종가들은 첨단 유전자형 및 표현형 분석 기술을 활용하고 이러한 특성을 좌우하는 근본적인 유전적 및 생리적 과정에 대한 보다 포괄적인 이해를 바탕으로 이러한 기대치를 더 잘 충족하는 작물을 개발할 수 있으며, 나아가 본 연구의 결과는 더 탄력 있고 수확량이 많은 고추 품종을 개발하는 데 도움이 될 수 있다.

APPENDIX- I. Varieties of chilies used in this study.

No.	IT number	Germplasm	Origin	Resource classification
1	IT113643	Sunsan Jaerae-2	KOR	Landrace
2	IT113703	Seungju Jaerae	KOR	Landrace
3	IT113724	Youngyang Jaerae	KOR	Landrace
4	IT158377	Enomi	JPN	NA
5	IT158433	C01511	ITA	NA
6	IT158626	HDA268	FRA	NA
7	IT158645	VAR6-1	MYS	NA
8	IT158647	PJ	MYS	NA
9	IT158648	1 CD	MYS	NA
10	IT158651	BUKIT GAMBIR	MYS	NA
11	IT158669	S.T.	THA	NA
12	IT158846	C01293	CUB	NA
13	IT158850	C01335	ZMB	NA
14	IT158859	C01396	ZMB	NA
15	IT158873	C01610	ZMB	NA
16	IT158876	C01665	ZMB	NA
17	IT158893	C01824	IRN	NA
18	IT158894	C01825	IRN	NA
19	IT158895	C01826	IRN	NA
20	IT163495	PI267732	PRI	NA
21	IT163500	PI297438	BRA	NA
22	IT163502	PI297488	BRA	NA
23	IT163508	PI322720	BRA	NA
24	IT163534	Chen-an	KOR	Landrace
25	IT164924	NP 46	UNK	NA
26	IT171362	83-168	CHN	NA
27	IT183648	PI123469	IND	NA
28	IT183651	Chilgaucle Ri Jo	MEX	NA
29	IT183652	Chilcote	MEX	NA
30	IT189942	Char ' Kovskii	UKR	NA
31	IT208425	70	UNK	NA
32	IT209941	10	UZB	NA
33	IT213251	Pusa jwala	IND	NA
34	IT218726	MYS-CGT-1999-99	MYS	NA
35	IT218753	PBC369 PBC369	IDN	NA
36	IT218755	Guajillo	MEX	NA

APPENDIX- I. Varieties of chilies used in this study (continued).

No.	IT number	Germplasm	Origin	Resource classification
37	IT218885	NPL-GYS-2004-44	NPL	Landrace
38	IT218895	WIR 191	MEX	NA
39	IT218937	Thailand14	THA	Landrace
40	IT219028	NPL-NIS-1998-90	UNK	NA
41	IT219847	NP34	IND	NA
42	IT219850	Barito	UNK	NA
43	IT221658	02G-130	UNK	NA
44	IT221680	06A-174	USA	Genetic Materials
45	IT221876	KC00043	ECU	NA
46	IT221877	KC00137	MYS	NA
47	IT221884	KC 857	VNM	NA
48	IT221900	KC01309	LAO	NA
49	IT221901	KC01310	LAO	NA
50	IT221904	KC01315	LAO	NA
51	IT221909	KC01323	LAO	NA
52	IT221910	KC01324	LAO	NA
53	IT221913	KC01327	LAO	NA
54	IT221914	KC01328	LAO	NA
55	IT223683	KC 00012	USA	Landrace
56	IT223686	KC 00048	USA	Landrace
57	IT223692	CMV 1166	HUN	Breeding Line
58	IT223700	VP 2	VNM	Landrace
59	IT223702	VP 10	VNM	Landrace
60	IT223706	VP 16	VNM	Landrace
61	IT223715	VP 28	VNM	Landrace
62	IT223717	VP 30	VNM	Landrace
63	IT223718	VP 32	VNM	Landrace
64	IT223742	VP 62	VNM	Landrace
65	IT223753	VP 79	VNM	Landrace
66	IT223755	VP 82	VNM	Landrace
67	IT223777	VP 106	VNM	Landrace
68	IT223780	VP 117	VNM	Landrace
69	IT225029	Sarga	27	Breeding Variety
70	IT228971	Early Jalapeno	USA	Breeding Variety
71	IT229664	PI586672	USA	NA
72	IT229979	CHILE JALAPENO	MEX	NA

APPENDIX- I. Varieties of chilies used in this study (continued).

No.	IT number	Germplasm	Origin	Resource classification
73	IT231157	Mesilla Hybrid	USA	Breeding Variety
74	IT231165	Numex Sunflare	USA	Breeding Variety
75	IT231172	Sweet Pickle	USA	Breeding Variety
76	IT231173	Red mushroom	USA	Breeding Variety
77	IT231179	Tam Jalapeno	USA	Breeding Variety
78	IT231186	Habanero brown	USA	Breeding Variety
79	IT231187	White Habanero	USA	Breeding Variety
80	IT231393	cayenne dedo de moca	UNK	Breeding Variety
81	IT235610	WIR6599	RUS	NA
82	IT235611	WIR1484	UZB	NA
83	IT235612	WIR1725	IND	NA
84	IT235613	WIR2231	IND	NA
85	IT235614	WIR2381	GEO	NA
86	IT235615	WIR2590	PAK	NA
87	IT235616	WIR2597	LBY	NA
88	IT235618	Laca Lepu Mo8	MEX	NA
89	IT235661	SLORI	TUR	Breeding Variety
90	IT235664	ZAKAZNOI 953	RUS	Breeding Variety
91	IT235865	Ribka	BGR	Landrace
92	IT235870	A7E0080	BGR	Landrace
93	IT235872	Kozirog	BGR	Landrace
94	IT235874	Kambi	BGR	Landrace
95	IT235875	A7E0166	BGR	Landrace
96	IT235877	Vanity	BGR	Landrace
97	IT235878	kapia	BGR	Landrace
98	IT235914	A7E0206	BGR	Landrace
99	IT235915	A7E0240	BGR	Landrace
100	IT235921	A7E0292	BGR	Landrace
101	IT236215	140	BOL	NA
102	IT236255	9	UZB	NA
103	IT236272	53	UZB	NA
104	IT236273	61	UZB	NA
105	IT236288	MC12	MYS	NA
106	IT236293	7	UNK	NA
107	IT236295	51	UNK	NA
108	IT236312	UZB-GJG-1998-2	UZB	NA

APPENDIX- I. Varieties of chilies used in this study (continued).

No.	IT number	Germplasm	Origin	Resource classification
109	IT236313	4	UZB	NA
110	IT236333	Uiryeong Jaerae	KOR	Landrace
111	IT236334	Jinyang Jaerae	KOR	Landrace
112	IT236336	Samyang Jaerae	KOR	Landrace
113	IT236337	Suwon Jaerae	KOR	Landrace
114	IT236339	H.Wax No.2	UNK	NA
115	IT236343	Cascavel	MEX	NA
116	IT236345	Hot Portugal	USA	NA
117	IT236346	San ta Fe Grand	UNK	NA
118	IT236347	PBC413 TAM Mildjalapeno-1	USA	NA
119	IT236348	PBC416 YJ81032	USA	NA
120	IT236349	PBC120 HDA336	FRA	NA
121	IT236350	PBC427 NuMex Eclipse	USA	NA
122	IT236351	PBC428 NuMex Sunset	USA	NA
123	IT236352	PBC429 NuMex Sunrise	USA	NA
124	IT236356	Hong Kong Red Chili	UNK	NA
125	IT236357	Long Chili455(NongWoo)F3	UNK	NA
126	IT236360	MilesFlavor se	UNK	NA
127	IT236361	Saeng Saeng 193F3	UNK	NA
128	IT236363	Szechwan4	TWN	NA
129	IT236364	Tit Super	IDN	NA
130	IT236365	95ThailandBKVM dried fruit	UNK	NA
131	IT236366	IN,JA,VM4	UNK	NA
132	IT236367	97H.B offype EmCu-22	UNK	NA
133	IT236371	Hu-33 AVRCD94187	UNK	NA
134	IT236373	Jungang Jongmyo-2000-6727	IND	NA
135	IT236374	Jungang Jongmyo-2000-6738	UNK	NA
136	IT236377	96IN F1se	UNK	NA
137	IT236385	97Inni Magelang	UNK	NA

APPENDIX- I. Varieties of chilies used in this study (continued).

No.	IT number	Germplasm	Origin	Resource classification
138	IT236386	Pusa Jwala	UNK	NA
139	IT236387	Hyderabad VM	UNK	NA
140	IT236390	98HES102 PBC100-6	UNK	NA
141	IT236392	98HES106 PBC30-4	UNK	NA
142	IT236394	Hot Chili Novartis F2	UNK	NA
143	IT236395	Jungang Jongmyo-2000-6854	UNK	NA
144	IT236396	Hot Chili Orissa local-3	UNK	Landrace
145	IT236397	AnKur-228	UNK	NA
146	IT236400	ChiangRai VM	UNK	NA
147	IT236401	PBC59 Bhaskar	UNK	NA
148	IT236402	PBC134 LCA-305	IND	NA
149	IT236403	PBC157 HuaySithon	THA	NA
150	IT236405	PBC479 ANK-72	LKA	NA
151	IT236408	PBC586 PBC586	THA	NA
152	IT236409	99Kunming collection1	UNK	NA
153	IT236410	99Kunming collection2	UNK	NA
154	IT236412	Tombak-2	UNK	NA
155	IT236413	Jungang Jongmyo-2000-6013	UNK	NA
156	IT236414	94PH-21	UNK	NA
157	IT236417	Jungang Jongmyo-2000-6094	UNK	NA
158	IT236420	B.Wonder	UNK	NA
159	IT236423	CM331	UNK	NA
160	IT236425	Jungang Jongmyo-2000-5033	UNK	NA
161	IT236426	Jungang Jongmyo-2000-5034	UNK	NA
162	IT236427	Sky Chili	KOR	Landrace
163	IT236428	Horse Horn Chili	KOR	Landrace
164	IT236429	Blue Dragon Chili	KOR	Landrace
165	IT236430	Seven Star Chili	KOR	Landrace
166	IT236431	Imsil Jaerae	KOR	Landrace
167	IT236432	Blue Dragon Chili	KOR	Landrace
168	IT236433	Anjilbaeng-i	KOR	Landrace

APPENDIX- I. Varieties of chilies used in this study (continued).

No.	IT number	Germplasm	Origin	Resource classification
169	IT236434	Subicho	KOR	Landrace
170	IT236435	Ttungttung Chili	KOR	Landrace
171	IT236436	Blue Dragon Chili	KOR	Landrace
172	IT236448	Oranjevyi kvadrat	RUS	Breeding Variety
173	IT236449	Gladiator	NLD	Breeding Variety
174	IT236451	Osh-kosh	RUS	Breeding Variety
175	IT236453	Bogatyri	RUS	Breeding Variety
176	IT236458	BINNI-PUX	RUS	Breeding Variety
177	IT236459	Krasnoe plamya	RUS	Breeding Variety
178	IT236460	Bolgarskii 79	RUS	Breeding Variety
179	IT236465	24B-2-1-4-2-2-1	UNK	Breeding Line
180	IT236466	24B-2-1-4-3-2-4	UNK	Breeding Line
181	IT236467	24B-2-1-4-3-4-1	UNK	Breeding Line
182	IT236468	24B-2-18-1-1-2-1	UNK	Breeding Line
183	IT236469	24B-2-18-1-1-2-3	UNK	Breeding Line
184	IT236470	24B-2-18-1-6-1-3	UNK	Breeding Line
185	IT236471	24B-2-18-3-3-1-1	UNK	Breeding Line
186	IT236532	Zumrad	UZB	NA
187	IT236755	Rajcatova paprika	27	Breeding Variety
188	IT236772	(RSS/LV2319)F5-B-3	UNK	Breeding Line

APPENDIX- II. *Capsicum annuum*

APPENDIX- II. *Capsicum. Annuum*

ID	Rep.	Leaf area	Leaf width	Leaf length	Stem length	Stem thickness	Stem angle	Flower area	Fruit area	Fruit length	Fruit width	Fruit thickness
IT113643	1	6577	72.9	146.7	319.5	18	53.3	279.2	110.3	22.9	6.3	2.4
IT113643	2	4042.5	52.3	125.1	282.7	28.1	44.7	.	110	23.3	6.4	2.5
IT113643	3	4717.2	58.2	123.9	275	23.9	59.2	.	110.7	23.5	6.3	2.1
IT113643	4	4234.2	60	113.8	.	.	.	.	94.9	23.1	6.4	1.9
IT113643	5	5095.9	58.2	137.6	.	.	.	.	115.1	24.4	6.4	1.9
IT113643	6	4148.2	57.2	117.3	.	.	.	.	102.9	23.4	6.1	2.3
IT113703	1	4646.7	59.7	123.8	444.9	24.2	47.7	279.6	95.9	21	6.8	0.9
IT113703	2	4261.4	54.7	120.9	427.1	22.9	58.7	.	95.7	20.9	6.5	1.1
IT113703	3	4663.5	59.6	124.6	306.4	34.6	38	.	73.3	17.9	5.6	1
IT113703	4	4188.4	58.6	116.9	.	.	.	.	78.3	18.2	5.6	1.4
IT113703	5	4650.5	59.6	123.8	.	.	.	.	94.1	23.5	6.1	1.3
IT113703	6	4182.6	58.6	116.8	.	.	.	.	88.1	23.7	6.2	1.2
IT113724	1	3886.3	52.5	114.5	326.1	22.2	60	247.5	115.3	28.3	6	1.4
IT113724	2	2356.4	42.5	88.3	327.1	21.6	47	.	133.5	28.2	5.8	1.1
IT113724	3	4258.2	55.7	123.5	256	27.7	66.4	.	117.9	26.4	7.1	1.3
IT113724	4	2701.2	44.1	100.4	.	.	.	.	112.9	26.4	6.6	1.3
IT113724	5	3623.7	45.1	125.1	.	.	.	.	120.3	30.9	5.5	1.3
IT113724	6	3096.1	48.8	103.7	.	.	.	.	101.5	30.1	5.1	0.9
IT158377	1	1821.8	33.2	78.4	196.8	51	32	191.6	28.9	7.9	4.7	0.9
IT158377	2	1604.1	33.4	69.3	147.9	13.3	45	.	28.3	7.8	4.8	0.9
IT158377	3	1719.2	35.8	78.1	153	31.9	49.8	.	23	7.2	4.4	0.8
IT158377	4	1283.9	29.1	63.8	.	.	.	.	22.7	7.2	4.3	0.8
IT158377	5	2121.3	39.3	86.8	.	.	.	.	24.3	7	4.6	0.5
IT158377	6	1234.5	29.5	64.1	.	.	.	.	24.6	7.1	4.7	0.6
IT158412	1	4228.3	57.7	114.1	297.9	25.5	38.3	114.8	7.6	7.4	1.5	0.4
IT158412	2	2490	41.2	92.7	267.3	21.3	49.3	.	7.7	7.5	1.5	0.4
IT158412	3	3310	47.4	110.7	245.2	24.1	58	.	8	7.1	1.7	0.4
IT158412	4	3460.5	52.1	102.8	.	.	.	.	8.1	6.8	1.8	0.4
IT158412	5	3896.1	57.8	124.6	.	.	.	.	7.8	7.1	1.5	0.3
IT158412	6	2190.1	37.8	92.5	.	.	.	.	7.8	6.9	1.6	0.3
IT158626	1	7485.9	77	152.1	299.9	25.5	62.6	246.9	90	15.5	7.9	1.9
IT158626	2	6019	70.5	138.7	414.5	29.8	46.2	.	89.2	15.6	7.9	2.2
IT158626	3	5956.6	65.5	140.5	468	37.2	28	.	91.1	15.4	7.7	1.5
IT158626	4	7093.1	76.4	139.7	.	.	.	.	88.1	15.6	7.4	1.7
IT158626	5	6057.7	67.3	148.1	.	.	.	.	89.8	16.1	7.1	1.2
IT158626	6	6964	72.3	146.7	.	.	.	.	92.3	16	7.3	1.5
IT158645	1	7007.7	71.6	156.3	385.6	29.3	42.7	369.5	146.5	31.4	6.7	1.8
IT158645	2	6225.3	69.5	156.6	461.1	19.1	42.3	.	132.7	30.8	6.5	1.4
IT158645	3	4356.2	53.2	131.1	494.1	21.5	36	.	132.8	32.5	6	1.4
IT158645	4	5054.7	53.9	152.4	.	.	.	.	113.9	31.3	5.6	1.3
IT158645	5	4190.3	55.2	125.4	.	.	.	.	138.1	35.2	5.9	1.5
IT158645	6	8121.1	67.9	185.7	.	.	.	.	141	35.3	5.8	1.3
IT158647	1	4126.3	53.6	121.4	616.8	28.3	77.5	256.1	120.4	18.8	8	1.2
IT158647	2	5114.5	62.5	123.9	543.9	39	44.5	.	118.5	18.9	8	1.7

APPENDIX- II. *Capsicum annuum*

APPENDIX- II. *Capsicum. Annuum* (continued)

ID	Rep.	Leaf area	Leaf width	Leaf length	Stem length	Stem thickness	Stem angle	Flower area	Fruit area	Fruit length	Fruit width	Fruit thickness
IT158647	3	4563.6	56.9	119.8	732.2	31.4	66	.	129.5	18.3	8.8	2
IT158647	4	4791.5	59.5	126.3	.	.	.	.	126.1	18.4	8.6	2.5
IT158647	5	4506.4	62.5	121.2	.	.	.	.	106.8	17.6	8	1.9
IT158647	6	4849.3	60.5	120.3	.	.	.	.	111.3	17.6	8.2	1.7
IT158648	1	4983	58.2	131.6	343.8	23.6	72	409.1	166.3	31	8.1	1.2
IT158648	2	6258.7	74.3	135.6	325.4	25.9	38.1	.	171.7	31.9	8.3	1.3
IT158648	3	5190.4	59.3	135.6	189.9	34.3	45.6	.	132.2	31.2	6.1	1.2
IT158648	4	8344.1	77.8	165.4	.	.	.	.	137.2	30.5	6.8	1.1
IT158648	5	3645.7	51.1	118.8	.	.	.	.	140	32.3	7.2	1.2
IT158648	6	5565.8	67.3	135.2	.	.	.	.	130.2	32	6.8	1.2
IT158651	1	3273.6	45.2	110.1	485.4	29.7	58.2	414.6	148.6	36.2	5.8	1.9
IT158651	2	2526.4	40.2	95.5	439.2	29.9	42.3	.	159.8	36.6	6.1	1.6
IT158651	3	4425.3	55.1	127.5	239.3	26.4	60.1	.	125.3	32.9	7.3	1.4
IT158651	4	3970.2	51.5	124.3	.	.	.	.	127.7	32.4	6.7	1.5
IT158651	5	3762.6	45	121.8	.	.	.	.	151.8	37.8	7.2	1.8
IT158651	6	4085.6	53.1	128.2	.	.	.	.	150.7	38.7	6.5	1.8
IT158669	1	5310.6	54.2	152.3	441.4	27	39.2	341.4	86.5	24.7	5.1	1.1
IT158669	2	5871.8	60.9	153.1	390	27.9	66.3	.	86.2	25.1	4.8	1.2
IT158669	3	5531.6	64.1	132.9	246.5	13.9	59.9	.	99.3	26.8	5.2	1.3
IT158669	4	5162.3	57.5	130.6	.	.	.	.	96.3	26.3	5.7	1.3
IT158669	5	6531.1	62.1	170.6	.	.	.	.	118.3	28.2	5.5	1
IT158669	6	5297.1	56.9	146.9	.	.	.	.	122.7	28.8	5.9	1
IT158846	1	2097.5	44.9	73.1	367	29	47.2	253.3	34.4	8.7	5	1
IT158846	2	1902.9	41.8	72.1	154.8	25.1	61	.	32.4	8.7	4.8	0.8
IT158846	3	2279.6	45.4	77.4	285.5	21.6	47.8	.	31.2	8.8	4.4	0.8
IT158846	4	1632.1	38.2	65.9	.	.	.	.	32.7	9.2	4.6	0.7
IT158846	5	2360.1	45.4	79.7	.	.	.	.	32.1	8.6	4.6	0.6
IT158846	6	2242.3	46.1	76.6	.	.	.	.	31	8.5	4.5	1
IT158850	1	1640.4	36.2	69.7	141.3	30.9	24.1	148.4	40.9	10.4	5.4	1
IT158850	2	1079.7	28.2	59.1	136.3	17.8	32.6	.	36.9	10.1	4.8	1
IT158850	3	1820.5	34.4	76.1	268.2	26.2	8.2	.	41.9	9.8	5.9	1.5
IT158850	4	1010	28.1	56.6	.	.	.	.	40	9.9	5.6	1.4
IT158850	5	1400.3	33.8	64.2	.	.	.	.	37.3	8.5	5.7	0.9
IT158850	6	2093.8	39.4	77.9	.	.	.	.	40.4	8.9	6.1	0.9
IT158859	1	4678.5	58.6	124.1	161	23.1	69.7	236.5	35.3	7	6.6	1.2
IT158859	2	3337.1	51	104.6	313	21	49.2	.	31.1	6.7	6	0.8
IT158859	3	4945.3	60.1	128.3	202.6	31	42.4	.	30.7	6.7	5.9	0.8
IT158859	4	3117.6	49.1	99.2	.	.	.	.	33.1	7	6.2	0.9
IT158859	5	4058.2	50.7	119.1	.	.	.	.	36.3	6.8	6.7	0.9
IT158859	6	3759.8	53.9	111.7	.	.	.	.	38	7.3	6.7	1
IT158873	1	5261.5	67	136.5	462.4	42.7	36.5	206.4	100.1	20.3	6	1.6
IT158873	2	3157.5	49.4	100.8	171.7	19.3	49	.	92	20.7	5.8	1.4
IT158873	3	4927.5	60.7	134.5	410.6	23.8	46.1	.	95.4	20.8	6	1.4
IT158873	4	2795.9	45.7	94.8	.	.	.	.	78.9	20.1	4.9	0.9
IT158873	5	5531.3	65.1	138.8	.	.	.	.	82.7	19.1	5.5	0.9

APPENDIX- II. *Capsicum annuum*

APPENDIX- II. *Capsicum. Annuum* (continued)

ID	Rep.	Leaf area	Leaf width	Leaf length	Stem length	Stem thickness	Stem angle	Flower area	Fruit area	Fruit length	Fruit width	Fruit thickness
IT158873	6	3673.3	54.4	105.2	.	.	.	.	86.2	18.9	6	1.1
IT158876	1	3086.3	44.5	102.5	158.6	23.8	31.5	224	20.1	6.1	4.7	1.1
IT158876	2	3096.1	44.2	102.8	136.1	23.2	49.6	.	21.1	6.2	5	1.2
IT158876	3	2283	39.3	87.6	181.9	21.4	40.6	.	32.5	8	6.1	1.2
IT158876	4	2252.4	40.5	83.7	.	.	.	.	30.3	8.2	5.5	0.9
IT158876	5	2326.6	42.3	90.8	.	.	.	.	23.6	7.1	4.8	0.9
IT158876	6	2721.6	42.5	99.8	.	.	.	.	24.4	7.1	5.3	0.8
IT158893	1	2809.7	42.1	107.9	397.8	31.4	70.6	284	74.9	17.6	6.1	1.2
IT158893	2	2299.5	40.8	83.8	230.2	18.1	47.5	.	72.5	17.8	5.6	1.1
IT158893	3	4403.9	59	119.5	288.3	22.9	67.9	.	83.5	18.7	5.8	1
IT158893	4	2534.7	48.1	85.5	.	.	.	.	86.8	19.3	6	1.3
IT158893	5	4173.3	58.3	114.6	.	.	.	.	76.1	17.1	7.3	1.5
IT158893	6	2240.3	40.9	93.4	.	.	.	.	76.8	18.1	5.8	1.2
IT158894	1	3372.2	52.1	101.7	193.7	22.8	52.1	340.9	74.7	14.9	6.7	1.8
IT158894	2	1588.7	29.8	79.2	235	17.8	49.4	.	79.9	15.1	7.1	2.1
IT158894	3	4074.3	50.9	124.8	154.2	22.1	46.2	.	84.2	15.7	7.9	1.5
IT158894	4	3216.5	44.7	119.6	.	.	.	.	79.9	16	7.1	1.2
IT158894	5	2569.5	41.1	102.5	.	.	.	.	57	12.3	5.8	1.3
IT158894	6	2375.3	41.5	92.3	.	.	.	.	58.9	12.4	5.7	1.5
IT158895	1	3104.4	47.7	99.1	201.9	28.5	48.2	477.1	132.7	26.8	7.3	1.4
IT158895	2	2840	46.8	97.1	163.6	22.7	45.6	.	133.4	26.2	7.3	1.6
IT158895	3	2707.1	43.2	97.8	166.9	22.9	43.1	.	167.6	29	8.9	1.8
IT158895	4	2692	49.5	95.4	.	.	.	.	168.6	29.4	7.9	1.7
IT158895	5	2618	43.7	101.9	.	.	.	.	135.9	26.6	9.1	1.1
IT158895	6	2031.9	35.1	95.1	.	.	.	.	145.4	27.5	8.6	1.5
IT163495	1	4828.1	61.7	123.1	267.1	30	86.5	244	103.7	20.8	6.6	1.5
IT163495	2	3944.9	57.2	114	292.1	31.6	48.6	.	101.4	21.4	6.5	1.4
IT163495	3	5524.7	65.6	134.3	244.3	21.6	54.5	.	100.7	21.1	6.7	1.3
IT163495	4	5109.6	62.9	134.8	.	.	.	.	98.9	20.9	6.9	1.2
IT163495	5	5746	64.8	139.4	.	.	.	.	90	19.8	6.5	1.3
IT163495	6	4553	63.6	114.2	.	.	.	.	98	20.2	6.4	1.3
IT163500	1	3555	47.1	121.6	388.5	31	57.4	330.6	99.5	30.4	4.7	1.3
IT163500	2	3034.7	47.1	106.2	346.1	21.3	52.3	.	89.1	30.1	4.6	1.2
IT163500	3	4543.3	56.9	126.8	322	19.3	58.6	.	74.7	27.4	4.7	1.2
IT163500	4	2593.4	42.7	102.4	.	.	.	.	69.2	26.3	4.5	1.2
IT163500	5	4424.3	56.7	129.9	.	.	.	.	79.9	30	4.1	1.3
IT163500	6	3445.7	49.3	114.5	.	.	.	.	81.7	29.7	4.4	1.2
IT163502	1	5355.3	58.1	143.6	372.5	19.7	77.6	291.6	124	19.3	8.7	1.7
IT163502	2	5325.1	59.9	134.5	395.5	25.8	71.9	.	122.7	19.4	8.5	1.5
IT163502	3	6200.1	67.1	157.8	401.2	32.2	68.5	.	120.3	18.3	8.7	1.3
IT163502	4	4676.8	57.7	122	.	.	.	.	121.5	19.2	8.7	1.2
IT163502	5	6178.2	65.8	137.6	.	.	.	.	117.1	17.8	8.6	1.2
IT163502	6	6180.4	73.2	131.1	.	.	.	.	120.9	18.5	8.6	1.1
IT163508	1	4690.1	58.3	136.4	370.5	20.9	46.2	343.2	71.9	21.6	6.1	1.2
IT163508	2	4788.2	59.2	129.9	290.8	21.2	59.2	.	71	21.9	6.2	1.1

APPENDIX- II. *Capsicum annuum*

APPENDIX- II. *Capsicum. Annuum* (continued)

ID	Rep.	Leaf area	Leaf width	Leaf length	Stem length	Stem thickness	Stem angle	Flower area	Fruit area	Fruit length	Fruit width	Fruit thickness
IT163508	3	3512.4	47.2	114.5	432.3	21.4	61.8	.	90.5	23.6	7.2	1.2
IT163508	4	3397.9	44.6	121.1	.	.	.	.	81	23.6	6.5	1
IT163508	5	4739	59.9	122.2	.	.	.	.	101.7	25.9	7.5	1.1
IT163508	6	4238.4	54.2	131.6	.	.	.	.	93.6	26.1	6.7	1
IT163534	1	5530.1	70.3	124.6	303.6	22.9	60.3	453.1	167.1	22	9.8	2.9
IT163534	2	2089.9	39.1	91	317.6	28.8	57	.	160.4	21.9	9.4	2.3
IT163534	3	2131.6	38.1	94	270.7	21.8	59.7	.	136	22	8.8	1.9
IT163534	4	1857.1	35.6	83.1	.	.	.	.	134.5	22	8.7	1.8
IT163534	5	3719.6	50.3	117.1	.	.	.	.	116.5	20.3	8	1.8
IT163534	6	3400.7	49.1	107.8	.	.	.	.	118.6	21.3	8.1	1.9
IT164924	1	4367.9	59.7	122.5	298.8	21.7	49.4	315.4	87.9	35.9	5.1	0.5
IT164924	2	3322.6	47.9	110.9	230.5	29.7	55.5	.	83.1	35.3	5.9	0.5
IT164924	3	44.9	4.5	12.4	294.4	22.3	71.5	.	101.6	36.1	9.6	1
IT164924	4	4297.4	53.8	129.8	.	.	.	.	101.1	36.5	6.2	1.1
IT164924	5	3690.3	53.7	110.2	.	.	.	.	103.7	40	5.9	0.8
IT164924	6	5882.9	69.4	144.4	.	.	.	.	93.2	40	5	0.9
IT171362	1	4334.1	57.8	112.2	520.5	33.7	53.2	234.9	27	11.8	3.3	0.7
IT171362	2	4903.8	69.2	118.8	534.1	23.1	57.1	.	22.7	11.3	3	0.7
IT171362	3	5309.2	70.3	127.5	489.3	30.5	43.1	.	29.9	13.2	3.6	0.7
IT171362	4	5419	68.9	129.5	.	.	.	.	29.4	13	4.1	0.6
IT171362	5	4614.5	62.9	116.8	.	.	.	.	21.7	11.3	3.1	0.6
IT171362	6	4431.6	61.5	114.5	.	.	.	.	26.6	11.7	3.4	0.8
IT183648	1	4007.9	56.4	113.3	203.1	29.3	46.9	326.3	89.4	21.7	5.8	1.2
IT183648	2	3410.5	50.1	108.4	231.1	29.4	58.6	.	90.2	21	5.7	1.1
IT183648	3	3903.9	48.5	130.2	287.5	19.9	51.4	.	92.8	20.8	6	1
IT183648	4	3479.4	50.1	113.6	.	.	.	.	84.6	20.8	5.8	1.1
IT183648	5	4572.1	56.6	127.1	.	.	.	.	91.1	22.5	6.6	1.2
IT183648	6	4573.7	60.1	120.6	.	.	.	.	102.3	22.7	6.8	1.3
IT183651	1	2934.4	46.5	94.8	174.7	16.8	62.9	385.9	119.7	17.6	8.8	2.2
IT183651	2	2271.2	41.2	87.2	151.4	23.6	53.1	.	121	17.8	9.3	2
IT183651	3	3533.4	50.9	109.2	177.7	18.8	52.3	.	105.8	17.6	8.2	1.5
IT183651	4	3239.4	49.5	98.9	.	.	.	.	103	17.5	8.1	1.4
IT183651	5	2875.3	46.4	97.8	.	.	.	.	80.9	16.1	7.8	1.3
IT183651	6	3063.4	51.5	97.8	.	.	.	.	83.4	16.4	7.2	1.5
IT183652	1	3297.5	46.6	110.4	282	24.6	62.9	297	83.2	19	7.2	1.6
IT183652	2	3195.5	47.8	101.2	449	25.9	68	.	85.6	19.2	7.7	1.7
IT183652	3	2451.7	39.4	95.4	358.4	27.9	61.8	.	87.7	19.3	6.1	1.9
IT183652	4	3105.3	46.7	103.8	.	.	.	.	91.2	19.3	6.2	1.5
IT183652	5	2735.7	42.4	100.5	.	.	.	.	79.1	18.6	5.6	1.6
IT183652	6	2436.5	38.7	94.6	.	.	.	.	78.9	18.5	5.5	1.5
IT189942	1	5213.8	62	135.5	198.6	17.6	72	386.3	168.8	25.9	9.2	2
IT189942	2	4185.2	55.4	114.8	220.4	16.4	69.4	.	166.9	26.2	9.2	2
IT189942	3	5319.3	60.8	122.5	222.4	17.2	73.1	.	198.6	26.1	10.6	2.6
IT189942	4	3079.6	46.4	104.1	.	.	.	.	191.1	25.8	10.2	2.7
IT189942	5	4883.6	61.7	118	.	.	.	.	208.6	26.6	11.5	2.5

APPENDIX- II. *Capsicum annuum*

APPENDIX- II. *Capsicum. Annuum* (continued)

ID	Rep.	Leaf area	Leaf width	Leaf length	Stem length	Stem thickness	Stem angle	Flower area	Fruit area	Fruit length	Fruit width	Fruit thickness
IT189942	6	5373.1	62.1	130.7	.	.	.	.	187.9	27.4	10.5	2
IT208425	1	7439.5	73.4	166.8	279.3	26.3	87.4	223.1	49.5	14.8	4.6	0.7
IT208425	2	4672	60.7	126.3	230.3	22.5	61.1	.	46.8	15.2	5.3	0.7
IT208425	3	7055.4	69.7	159.1	271.6	20.7	59.1	.	51.9	15.6	4.4	0.9
IT208425	4	3650.2	50.1	113.7	.	.	.	.	50.1	16.3	4.1	0.9
IT208425	5	5194.8	63.7	137	.	.	.	.	41.3	14.7	3.6	0.9
IT208425	6	4827.2	59.2	137	.	.	.	.	40.8	15.5	3.8	0.9
IT209941	1	8263.4	85.5	158.4	334	33.7	49.2	438.1	273.6	21.9	15.8	3.9
IT209941	2	5668.5	63.7	149.5	320.1	27	49.6	.	289.2	22.6	16.4	5.1
IT209941	3	8498.7	84.7	164.4	331.5	22.8	50	.	298.6	22.7	16.5	5.5
IT209941	4	6334.1	69.8	142.9	.	.	.	.	285.3	22.4	16.3	4.5
IT209941	5	6771.7	70.7	153.7	.	.	.	.	387.1	30.5	16.2	5.2
IT209941	6	6799.5	70.9	151.7	.	.	.	.	378.6	29.7	16.5	5.1
IT213251	1	5854.7	68.2	144	360.9	22.7	76.1	279.4	87.3	29.2	4.4	1
IT213251	2	3913	51.1	119.1	359.8	22.6	44.7	.	86.2	29.5	4.3	1.1
IT213251	3	5205.6	62.8	136.1	388.5	26	53.1	.	80.9	29.5	4.4	0.9
IT213251	4	4857.9	62.1	133.6	.	.	.	.	80.5	29.5	4.8	0.9
IT213251	5	5082.6	61.2	137.5	.	.	.	.	84.8	31	5.3	1.1
IT213251	6	4338.5	53.9	133.5	.	.	.	.	96.9	31.3	4.9	1.1
IT218726	1	7388.5	75.2	158.7	407.9	23.2	47.2	259.1	123.3	41.4	5.4	1.8
IT218726	2	7605.8	75.4	155.3	331	24.1	33.3	.	102.2	39.9	7.6	1.3
IT218726	3	9502.1	84.1	184.9	366.1	22.1	60.4	.	116.8	41	5.6	1.4
IT218726	4	4719	60.2	125.2	.	.	.	.	108.5	39.4	5.2	1.7
IT218726	5	8937	76.6	182.8	.	.	.	.	109	40.1	5.6	1.1
IT218726	6	5805.4	70.5	139	.	.	.	.	121.3	41.6	5.3	1.5
IT218753	1	4649.5	54.7	126.4	178	20.2	50.4	392.4	100	21.7	5.6	2
IT218753	2	4926.9	60.4	127.2	165.3	16.1	48.7	.	92.1	21.4	5.7	2.1
IT218753	3	4420.4	55.9	123.7	239.8	25.7	46.2	.	117.5	23.7	6.8	2.6
IT218753	4	4559.7	56	118.9	.	.	.	.	118	23.8	6.7	2.3
IT218753	5	4239.3	55.9	127	.	.	.	.	122.3	21.4	7.6	2.7
IT218753	6	4527.4	56.6	123.1	.	.	.	.	117.5	21.4	7.1	2.5
IT218755	1	4227.6	56.7	124.8	302.8	17.2	35.9	525.7	129.2	35	7.8	1.7
IT218755	2	3728.1	53.3	120.9	298.1	16.1	34.4	.	125.6	35.3	7.4	2
IT218755	3	3818.6	53.3	120.5	301.9	14.4	59.4	.	150.9	34.8	9.5	1.8
IT218755	4	3659	56	112.2	.	.	.	.	151.5	34.7	10.8	2.2
IT218755	5	4880.8	63.5	131.3	.	.	.	.	138.1	35.6	5.7	2.2
IT218755	6	4310.8	55.7	124.2	.	.	.	.	143.2	35.9	6.4	2
IT218885	1	4222.1	50.3	143.1	359.5	25.7	50.8	600	81.2	28.2	7.6	1.3
IT218885	2	4036	51.9	129.3	287.1	35.6	33	.	78.8	28.3	6.2	1
IT218885	3	5333.1	54.9	157.8	319.3	26.1	46.2	.	105.7	36.9	6.6	1.3
IT218885	4	3658.4	43.4	134.6	.	.	.	.	96.3	37	6.9	1.4
IT218885	5	5603.6	61.1	154.3	.	.	.	.	93.7	33.9	11.9	1.1
IT218885	6	3424.5	39.7	137.1	.	.	.	.	99.4	34.8	8.8	1.1
IT218895	1	4616.1	55.1	136.5	193.1	20.7	65.8	401.4	121.3	23.8	8.2	1.7
IT218895	2	4201.7	56.4	120.6	192.1	21	64.9	.	122.8	24.4	8.1	2.4

APPENDIX- II. *Capsicum annuum*

APPENDIX- II. *Capsicum. Annuum* (continued)

ID	Rep.	Leaf area	Leaf width	Leaf length	Stem length	Stem thickness	Stem angle	Flower area	Fruit area	Fruit length	Fruit width	Fruit thickness
IT218895	3	4240.9	53.5	132	151	29.5	42.2	.	120.3	21.7	9.3	1.7
IT218895	4	3049.6	45.5	112.2	.	.	.	.	118.2	21.7	8.6	1.6
IT218895	5	5270.1	56.5	157.2	.	.	.	.	116.5	24.8	6.9	1.9
IT218895	6	3701.2	52.7	118.3	.	.	.	.	115.4	24.6	7.4	1.4
IT218937	1	7042.7	72.7	162.2	307.6	15.8	51	495.5	216.1	36.1	10.3	2
IT218937	2	5350.3	67.2	137.5	263.4	25.7	73.5	.	199.7	37.7	9.3	1.7
IT218937	3	5315.8	66.3	130.5	296.6	17.3	51.9	.	180.9	32.6	12	2
IT218937	4	4732.3	61.5	127.7	.	.	.	.	164.7	33.6	8.1	1.9
IT218937	5	9096.5	90.5	165.4	.	.	.	.	158.6	30.3	8.2	1.5
IT218937	6	4173.1	55.4	116.3	.	.	.	.	154.4	30.5	7.5	1.3
IT219028	1	5600	66.4	142.5	261.7	14.3	105.9	264	70.9	26.8	3.7	0.9
IT219028	2	5593.2	68.5	136.8	313.6	17.4	50.5	.	63.7	26.9	3.8	0.7
IT219028	3	5498.4	61.2	147.1	394	16.4	77.9	.	78.4	28.5	3.9	1.1
IT219028	4	5699.2	66.5	137.5	.	.	.	.	74.1	28.4	4	0.9
IT219028	5	8870.6	84.6	169.7	.	.	.	.	69.4	30	5.5	0.7
IT219028	6	5154.9	59.9	138.1	.	.	.	.	70.8	30.9	4.4	0.9
IT219847	1	5697	56.8	158.4	302.3	28.5	59.9	224.7	73.9	25	8.2	1.1
IT219847	2	4525.2	54.6	138.4	289.4	21.5	94.3	.	83.5	25.6	7.4	1
IT219847	3	4628.6	52.1	142.2	318.5	27	43.6	.	64.9	20.6	8.5	1.1
IT219847	4	4818.2	58.1	135.8	.	.	.	.	66.5	21.2	7.8	0.9
IT219847	5	4443.5	53.2	136.7	.	.	.	.	66.9	23.4	5	0.8
IT219847	6	5010.7	56.7	147.5	.	.	.	.	62.7	23.8	4.5	0.8
IT219850	1	4152.6	54.7	133.2	327.5	33.6	32.8	294.9	126.8	45.4	6	1.2
IT219850	2	3622.1	50.7	118.8	323.7	35.8	59.4	.	122.2	45	7.2	1.1
IT219850	3	4396.7	52.3	135.6	334.1	21.4	43.4	.	114.6	41.5	5.9	1.2
IT219850	4	4554	55.8	134.5	.	.	.	.	118.7	42.9	4.5	1.2
IT219850	5	6602	66.9	162.1	.	.	.	.	146.2	45.4	6	1.5
IT219850	6	5397.2	58.9	152.2	.	.	.	.	141.8	44.4	6.1	1.5
IT221658	1	6975	73.8	161.1	339.1	25	69.8	224.9	74.8	24.8	4.4	0.9
IT221658	2	9521.3	81.7	195.7	321.5	24.3	50.6	.	71.6	25.1	5.3	0.9
IT221658	3	9392.3	82.8	186.7	372	20.5	45.9	.	61.5	26	4.8	1
IT221658	4	7834.4	77.9	172.1	.	.	.	.	61.8	26.1	4.2	0.9
IT221658	5	8292.8	78.7	174.8	.	.	.	.	81.9	24.6	8.1	0.9
IT221658	6	6826.6	71.9	157.7	.	.	.	.	86.4	25.6	6.1	1.1
IT221680	1	6922.2	70.4	159.9	308.8	20.2	66	424.6	244.1	38.6	12.1	2.5
IT221680	2	5835.1	64.4	148.7	296.9	30.7	74.9	.	215.1	37	13.4	2.3
IT221680	3	6073.7	64.2	148.3	357.5	23.8	58.3	.	267.1	38.6	10.2	1.9
IT221680	4	4096.6	55.4	120	.	.	.	.	250.1	38.6	10.1	1.8
IT221680	5	5771.6	64	146.9	.	.	.	.	203.1	39	8.1	2.3
IT221680	6	5731.1	65.2	140.8	.	.	.	.	264.3	40.9	9.7	2.7
IT221876	1	5262.1	58.7	148.8	206.9	19	65.3	313.5	86.5	31.2	5.2	1
IT221876	2	4016.1	51.8	133.4	196.7	21.8	64.6	.	98.4	31.2	5.4	0.8
IT221876	3	4523	57.7	140.1	161.8	22.4	59.8	.	104.3	34.3	4.4	0.9
IT221876	4	3450.8	47.6	123.7	.	.	.	.	112.6	35	5.4	1
IT221876	5	4119.9	54.6	136.2	.	.	.	.	94.8	34.9	6.2	0.9

APPENDIX- II. *Capsicum annuum*

APPENDIX- II. *Capsicum. Annuum* (continued)

ID	Rep.	Leaf area	Leaf width	Leaf length	Stem length	Stem thickness	Stem angle	Flower area	Fruit area	Fruit length	Fruit width	Fruit thickness
IT221876	6	5044	61.3	135.1	.	.	.	.	90.2	34.5	6.5	1.2
IT221877	1	9047.1	87.9	177.9	379.3	23.7	47.3	304.7	83	27.2	4.7	1.6
IT221877	2	6672	69.9	163.3	336.7	17.6	65.1	.	85.5	27.4	4.9	1.3
IT221877	3	7945.8	73.5	183.8	371.1	20.3	62	.	83.6	27.1	5.4	1.2
IT221877	4	7077	66.6	178.8	.	.	.	.	82.3	27.4	4.8	1
IT221877	5	9882.2	85.1	197.3	.	.	.	.	65	26	6.5	1.1
IT221877	6	8120.3	68.1	195.6	.	.	.	.	68.9	26.7	5.2	1
IT221884	1	8431.6	73.5	187.6	303.3	17.1	41.1	239.9	131.2	23.8	7.1	2.4
IT221884	2	6123.3	67.9	157.3	289.9	22.2	59.2	.	138	23.7	7.4	2.4
IT221884	3	4445.6	55.1	133.1	236.2	22.2	40.2	.	115.2	22.7	7.3	1.5
IT221884	4	6761.4	67.5	169.4	.	.	.	.	119.6	22.8	7.1	2.1
IT221884	5	7253.9	73.5	160.8	.	.	.	.	121	24	7.1	1.6
IT221884	6	5923.3	65	164.2	.	.	.	.	121	24	7.4	1.9
IT221900	1	6491.5	70.8	148.4	377.6	16.5	71	239.2	42.5	14.9	3.9	0.8
IT221900	2	6326.2	65.5	156.6	302.5	26.3	83.1	.	32.6	14.7	3.2	0.8
IT221900	3	5605.6	63.6	151.5	364.5	23.1	75.8	.	32.8	14.5	3.2	0.8
IT221900	4	4717.5	59.4	127.5	.	.	.	.	28.9	13.6	3.1	0.6
IT221900	5	6713.3	67.5	156.5	.	.	.	.	35	13.8	3.4	0.8
IT221900	6	6837.7	77.4	145.3	.	.	.	.	31.7	14	3	0.7
IT221901	1	8364.9	81.3	170.8	371.4	17	65.5	390.2	92.5	24.5	6.2	1.4
IT221901	2	6809.4	74.7	159.1	300.5	15.9	61.9	.	91	24.6	6.3	1.3
IT221901	3	7850.2	75.5	165.2	306.6	17	43.5	.	81.9	24.8	5.2	1.3
IT221901	4	4478.9	61.9	117.5	.	.	.	.	85	25	4.9	1
IT221901	5	6168.2	67.7	151.8	.	.	.	.	92.1	23.5	6	1.2
IT221901	6	7854.2	80.7	159.9	.	.	.	.	103	24.1	6.1	1.3
IT221904	1	6890.8	69.7	153.7	338.7	29.2	69.9	331.5	72.4	27	5	0.9
IT221904	2	7885.7	77.4	173.4	380.4	57.9	46.9	.	76.3	27.3	5.5	1.3
IT221904	3	8014.6	76.8	165.3	373.2	53.3	70.1	.	73.2	27.4	8.5	1.2
IT221904	4	6634.8	67.5	156.7	.	.	.	.	74.1	28.3	6.7	1
IT221904	5	9246.4	78.1	190	.	.	.	.	49.3	23.5	4.5	0.9
IT221904	6	6802.8	70.1	153.8	.	.	.	.	55.5	23.7	5.3	0.9
IT221909	1	5890.9	66.1	152.8	333.9	25.1	75.6	279.6	46.6	14.7	4.1	0.9
IT221909	2	5118.9	58.2	151.3	276.5	23.9	51.8	.	43.1	14.2	4.3	0.9
IT221909	3	10228	89.1	180	352.3	27.3	59.8	.	46.4	14.4	4.4	1.1
IT221909	4	5330.3	63.4	137.6	.	.	.	.	47.4	14.5	4.6	0.9
IT221909	5	4883.8	59.1	134.2	.	.	.	.	47.9	13.8	4.5	1
IT221909	6	10014	87.9	179.6	.	.	.	.	47.6	14.3	4.3	1
IT221910	1	6176.1	61.7	162.9	414.4	23.9	45.3	243.1	36.1	14.7	3.4	1
IT221910	2	8343.8	77.2	183.1	328	20.8	65.1	.	34.2	15	3.4	0.7
IT221910	3	6734.9	64.3	169.3	387.9	22.1	54.9	.	33.5	15.3	3.2	1.1
IT221910	4	6752	73.3	155.2	.	.	.	.	32.5	15.2	3.1	1
IT221910	5	5925.8	64.5	152.9	.	.	.	.	39.9	15.6	3.7	1.1
IT221910	6	7364.3	77.7	165.5	.	.	.	.	36.7	15.6	3.5	1
IT221913	1	7341.3	65.9	180.2	310.8	23.2	67.6	249	86.9	31.8	4.8	1
IT221913	2	5727.9	58.4	166.7	290.3	22.1	55.2	.	73.9	29.8	4.9	1.1

APPENDIX- II. *Capsicum annuum*

APPENDIX- II. *Capsicum. Annuum* (continued)

ID	Rep.	Leaf area	Leaf width	Leaf length	Stem length	Stem thickness	Stem angle	Flower area	Fruit area	Fruit length	Fruit width	Fruit thickness
IT221913	3	7563	70.5	175.1	313	22.8	59	.	92.4	32	5.8	1.2
IT221913	4	5487.5	57.9	151.5	.	.	.	.	82.6	30.4	6.5	1.1
IT221913	5	5406.4	59.2	146.6	.	.	.	.	86.3	30.1	4.6	1
IT221913	6	7034.9	64.2	185.7	.	.	.	.	86.8	29.8	5	1
IT221914	1	9831.9	79.7	213.5	313.1	21.5	55.4	333.1	103.3	31	4.6	1
IT221914	2	8283.1	76.4	180.9	299.2	22.1	65.3	.	107.1	30.9	5	1.1
IT221914	3	8999.9	74.7	195.7	298.4	16.7	77.7	.	92.9	29.7	5.8	1
IT221914	4	8494.4	77.5	183.9	.	.	.	.	81.7	29.5	5.8	1
IT221914	5	8706.9	78.7	179	.	.	.	.	84.5	29.3	4.8	1.2
IT221914	6	9996.1	83.1	191.5	.	.	.	.	92.5	30.1	4.6	1.1
IT223683	1	4839.4	56	136.8	173.2	17.7	45.5	256.1	64	22.4	3.7	1.1
IT223683	2	4556.6	55.4	132.7	215	18.5	46.4	.	59.5	22.6	3.8	0.8
IT223683	3	4253.9	52.7	130.6	186.9	28.3	51.9	.	65.7	23.7	8.6	1.1
IT223683	4	3649.1	52.2	118.9	.	.	.	.	59.3	24.2	6.1	1
IT223683	5	3857.6	46	142.2	.	.	.	.	70.9	25.7	4.7	1
IT223683	6	4123.4	55.4	126.4	.	.	.	.	76.9	25.8	5.8	0.9
IT223686	1	3979.9	48.3	132	285.9	27.7	67.2	294.8	112	29.7	6.7	1.7
IT223686	2	3704.1	54.2	104.3	226.5	24.9	69.8	.	116.4	32	6.2	1.8
IT223686	3	5296.1	56.1	143.8	.	.	.	.	120.7	28	8.3	1.6
IT223686	4	3247.1	47.5	112.4	.	.	.	.	122	28.2	7.5	1.6
IT223686	5	4464.5	52.6	134.7	.	.	.	.	121.9	28	7.6	1.3
IT223686	6	5083.3	59.7	138.6	.	.	.	.	110.4	28.1	7.5	1.6
IT223692	1	4699.6	66.5	109.7	356.5	20	69	392.7	172.4	23.4	10.2	3.9
IT223692	2	9193	96.4	155.3	394.6	21.5	67	.	181.5	23.8	10.5	2.7
IT223692	3	5824.3	72.4	126.2	355.8	18.5	49.5	.	192.3	26.7	10	2.6
IT223692	4	7354.6	86.3	137.5	.	.	.	.	201.3	26.7	10.6	2.4
IT223692	5	5275.7	69.9	118.2	.	.	.	.	179.5	24.2	10.2	2.2
IT223692	6	5880.7	77.8	121.3	.	.	.	.	179.3	23.3	10.7	2.7
IT223700	1	6732.2	67.2	164.4	438.3	18.2	56.5	360.5	126.1	38	4.7	1.8
IT223700	2	5757.8	65.5	149.5	380.7	14.9	73.3	.	123.8	37.3	5.1	2.1
IT223700	3	8865.4	72.5	187.6	356.5	19.6	62.3	.	139.2	37.8	5.4	2.1
IT223700	4	7960.4	71.2	179.2	.	.	.	.	138.1	37.8	6.4	1.8
IT223700	5	5892.6	59.2	153.7	.	.	.	.	119.3	35	6.9	1.9
IT223700	6	6788.2	67.1	163.2	.	.	.	.	134.7	35.8	7.2	1.6
IT223702	1	4745.2	57.4	135.3	239.7	20	54.8	475	192.3	44.2	5.9	2.4
IT223702	2	5225.4	61.4	147.8	228.3	24	43.9	.	196.3	44.2	6.1	2.6
IT223702	3	4135.7	54.5	125.8	245.4	23.6	46.8	.	156.1	39.6	6.1	2.2
IT223702	4	4208.8	58.2	126.4	.	.	.	.	158.7	41.7	6.3	2.1
IT223702	5	6646.1	68.7	171.8	.	.	.	.	181.9	35.9	8.4	2.9
IT223702	6	5355.2	61.5	148.8	.	.	.	.	174.8	36.2	7.9	2.8
IT223706	1	2983.6	43.7	109	172.3	22.3	45.2	234.3	137	32.9	13.1	1.6
IT223706	2	3439.3	49.8	111.7	170.5	30.3	49.9	.	139.8	33.5	12.6	1.3
IT223706	3	4371	52	136.9	180	34	41.8	.	147.3	37.7	8	1.4
IT223706	4	4328.6	48.8	137.2	.	.	.	.	140.4	38.4	7.2	1.5
IT223706	5	3192	46.4	107.4	.	.	.	.	110.8	36.9	7.7	1.4

APPENDIX- II. *Capsicum annuum*

APPENDIX- II. *Capsicum. Annuum* (continued)

ID	Rep.	Leaf area	Leaf width	Leaf length	Stem length	Stem thickness	Stem angle	Flower area	Fruit area	Fruit length	Fruit width	Fruit thickness
IT223706	6	2887.1	46.1	107.5	.	.	.	.	113.1	36.2	9	1.3
IT223715	1	5007.5	58.2	143.5	201.2	20.9	42.5	273.3	136.1	32.1	8.9	2.1
IT223715	2	4028.8	54.9	122.4	163	20.4	56.2	.	132.4	32.5	7.8	1.9
IT223715	3	3207	41	122.8	180.3	20	85	.	134.3	36.2	5.2	2
IT223715	4	2808.2	40.9	114.3	.	.	.	.	131.7	35.2	6.5	1.8
IT223715	5	5206.6	60.7	145.2	.	.	.	.	142.6	32.9	16	1.5
IT223715	6	5263.5	58.8	146.9	.	.	.	.	151.5	34	14.5	1.7
IT223717	1	2983.9	40.4	117.2	173.3	22	47.3	309.3	144.3	33.8	7.9	1.6
IT223717	2	2834.9	42	106.7	171.4	21	47.3	.	153.2	33.7	9.1	1.4
IT223717	3	2548.5	39.3	100.7	152.5	25.3	72.6	.	173.2	32.9	8.9	1.6
IT223717	4	2726.8	42.7	108.5	.	.	.	.	173.8	34.4	8.2	1.9
IT223717	5	2817.7	42.3	111.2	.	.	.	.	152.9	32.5	9	1.7
IT223717	6	3113.4	44.8	112.1	.	.	.	.	148.1	32.6	9	1.2
IT223718	1	2362.6	38.2	102.2	185.5	18	47.9	285.7	122.7	35.7	16.9	1
IT223718	2	2159.5	36.7	101	201.6	20	53.2	.	102.5	34.5	15.7	1.3
IT223718	3	2961.5	40.3	122.2	199.4	20.5	46	.	103.5	38.8	9.8	1.3
IT223718	4	2292.3	35.4	104	.	.	.	.	100.2	38.9	10	1.1
IT223718	5	3519.2	47.2	125.4	.	.	.	.	113.9	39.9	7.3	1
IT223718	6	2686.2	41.8	111.8	.	.	.	.	108.7	40.4	6.8	1.4
IT223742	1	4223.2	52.1	133.9	193.6	24.6	40.2	321.5	250.8	40.6	7.8	1.4
IT223742	2	4178	55.6	129.2	186.9	22.6	41.2	.	212.1	39.7	7.7	1.7
IT223742	3	5227.1	58.1	143.8	158.7	23.6	70.7	.	202.7	39.5	9	1.6
IT223742	4	4656.7	55.8	138.5	.	.	.	.	180.8	39	10.2	1.3
IT223742	5	5189.1	58.3	147.7	.	.	.	.	190.1	38.7	10.2	1.2
IT223742	6	5558.3	57.2	158.2	.	.	.	.	169	40.2	8.4	1.2
IT223753	1	4079.6	51.7	127.1	195.3	22.4	47.9	283.2	304.5	27.8	14.9	3.4
IT223753	2	4506.4	54.8	134.9	160.9	24.8	53.4	.	296.7	27.9	14	2.6
IT223753	3	4949.6	54.3	150.5	156.3	19.3	40.5	.	332.9	29.9	13.9	2.6
IT223753	4	6422.4	66.9	159.5	.	.	.	.	320.3	29.5	13.7	2.2
IT223753	5	5648	64.5	149.1	.	.	.	.	337.9	29.3	15.9	2.3
IT223753	6	4907.7	56.4	142.4	.	.	.	.	347.3	30.6	16.4	2.7
IT223755	1	4454.6	55.8	138.6	244.7	23	52.7	405.5	142.5	35.9	5.6	1.2
IT223755	2	3914.3	53.3	123.4	321	18.7	58	.	141.4	36	5.6	1.8
IT223755	3	4691.1	54.1	145.8	270.4	18.5	43	.	135.1	36.1	8.7	1.6
IT223755	4	4713.7	52.1	143.6	.	.	.	.	132.3	37.5	6.1	1.4
IT223755	5	5315.1	61.3	149.5	.	.	.	.	104.1	30.8	6.1	1.2
IT223755	6	4712.2	54.2	140.3	.	.	.	.	110.6	31	5.8	1.2
IT223777	1	5195.6	58.5	145	280.7	21.3	40.6	452.4	114.6	19.8	7.6	2.4
IT223777	2	5509.2	60.6	157.6	301.1	21.6	56.2	.	112	19.4	7.5	2.5
IT223777	3	5800.4	67.3	152.7	247.9	21.4	47.6	.	118	18.8	8.3	2.3
IT223777	4	4355	54.8	125.5	.	.	.	.	119.1	19.2	7.9	2.6
IT223777	5	6086.2	66.6	152.7	.	.	.	.	114.3	17.7	8.3	2.5
IT223777	6	4423.1	53.2	130.7	.	.	.	.	114.7	17.6	8.4	2.5
IT223780	1	5324	66.8	123.5	285	21.1	41.2	235.4	89.7	12.4	9.1	3.1
IT223780	2	5110.4	62.4	129.9	270.6	24.3	63.9	.	90.8	12.6	9.2	3.4

APPENDIX- II. *Capsicum annuum*

APPENDIX- II. *Capsicum. Annuum* (continued)

ID	Rep.	Leaf area	Leaf width	Leaf length	Stem length	Stem thickness	Stem angle	Flower area	Fruit area	Fruit length	Fruit width	Fruit thickness
IT223780	3	5342.9	67.7	130.9	276.6	27.8	41.1	.	94	14.2	8.8	3.1
IT223780	4	5384.9	68.4	125.9	.	.	.	.	91.7	13.7	8.7	2.4
IT223780	5	5630.2	69.1	127.4	.	.	.	.	85.3	12.8	8.6	2.4
IT223780	6	6393.7	81.9	132.1	.	.	.	.	84.5	12.6	8.8	2.8
IT225029	1	2872.3	43.7	103.2	150.3	18.8	53.8	189.3	72.1	15	6.5	1.8
IT225029	2	3001.9	46.5	108.1	132.8	20.6	44.9	.	67.4	14.9	6.1	1.8
IT225029	3	2530.2	39.4	101.5	143.2	14.6	37.4	.	61.9	15.3	5.6	2
IT225029	4	2378.6	40.7	91	.	.	.	.	59.4	15.4	5.5	2.2
IT225029	5	2293.4	38.6	93.3	.	.	.	.	63.4	16.1	5.5	1.9
IT225029	6	2431	42.6	93.3	.	.	.	.	60.9	15.6	5.7	1.9
IT228971	1	7306.4	74.3	163.5	177	17.9	53.1	453.2	99.5	14.8	8.5	3.1
IT228971	2	6490.1	68.8	158.7	197.5	18.4	44.8	.	88.4	14.4	7.9	2.5
IT228971	3	6193.3	62.4	157.6	172.7	17.8	46	.	84	15.9	7.1	2.4
IT228971	4	6949.2	72.9	162.6	.	.	.	.	85.8	14.9	7.3	2.5
IT228971	5	5663	65.1	140.7	.	.	.	.	89.8	14.4	7.8	2.3
IT228971	6	7280.5	73.3	167.7	.	.	.	.	98.8	14.8	8.6	2.5
IT229664	1	4301.8	61.5	108.4	150.7	22.3	39.8	277.8	189.9	22.9	10.5	2.9
IT229664	2	3962.9	57.4	105.4	178.2	16.4	55.9	.	196.4	22.8	10.9	1.8
IT229664	3	4449.3	63	104.4	155.1	15.8	59.8	.	183.8	23.1	10.3	2.1
IT229664	4	4319.2	62.8	101.5	.	.	.	.	186.4	23.2	10.6	2.3
IT229664	5	4047.4	56.7	110.5	.	.	.	.	196.3	23.9	10.9	2.1
IT229664	6	4264.6	57.9	108.3	.	.	.	.	191.4	24.3	10.5	1.7
IT229979	1	6661.8	70.7	151.8	236.2	27.9	43.7	479.3	115.7	18.2	8.3	2.9
IT229979	2	6130.9	68.7	143.4	170	30.8	43	.	112	17.9	7.9	2.7
IT229979	3	5006.1	63.7	124.1	243.6	32.2	44.7	.	110.5	18.3	7.7	2.7
IT229979	4	9331.5	89.9	163.2	.	.	.	.	108.2	18.6	7.2	2.7
IT229979	5	6097.9	64.1	151.6	.	.	.	.	114.3	18.7	7.8	2.9
IT229979	6	4720.7	55.5	138.1	.	.	.	.	114.5	19	7.6	2.7
IT231157	1	9346.8	94.4	170	251.3	28.6	43.3	472.8	340.3	51.5	10.6	2
IT231157	2	9914.6	86.5	186.9	210.5	20.9	72.7	.	302.8	50.9	9.4	2
IT231157	3	7893.3	85.6	153.9	251.5	17.8	68.8	.	244.8	44.4	11.1	1.7
IT231157	4	9236	88.6	168.4	.	.	.	.	245.5	47.2	8.2	1.5
IT231157	5	9934.6	86.4	185.6	.	.	.	.	240.8	46.5	8.1	1.5
IT231157	6	11031	95.2	186.2	.	.	.	.	249.6	43.9	12.1	1.6
IT231165	1	4275.6	59.8	120.6	141	12.1	57.7	452.9	66.5	19.7	5.2	1.5
IT231165	2	3324.3	53.4	101.3	164.3	13.7	55.2	.	65	19.7	5	1.1
IT231165	3	4950.6	63.4	135.7	154.8	15.7	57.2	.	67.5	21.3	5.7	1.1
IT231165	4	4282.2	54.6	128.3	.	.	.	.	67.4	21	4.9	1
IT231165	5	.	.	.	.	.	.	.	51.9	19.6	3.9	0.8
IT231165	6	.	.	.	.	.	.	.	58.6	21.4	4.4	0.9
IT231172	1	3986.1	63.4	111.1	195.3	15	42.5	390.3	138	20.6	9.6	2.8
IT231172	2	3811.7	52.2	117.9	190.5	18.8	45.1	.	137	20.3	9.5	3.2
IT231172	3	4018.3	58.9	112.7	170.8	18.3	53.4	.	124.2	20.4	8.2	2.6
IT231172	4	3425.7	54.2	99.1	.	.	.	.	136.3	21.2	8.5	3.4
IT231172	5	.	.	.	.	.	.	.	101	19.1	8.5	3.3

APPENDIX- II. *Capsicum annuum*

APPENDIX- II. *Capsicum. Annuum* (continued)

ID	Rep.	Leaf area	Leaf width	Leaf length	Stem length	Stem thickness	Stem angle	Flower area	Fruit area	Fruit length	Fruit width	Fruit thickness
IT231172	6	.	.	.	.	.	.	.	110.6	20.1	8.3	3
IT231173	1	9153.1	89.9	172.5	189.3	26.7	31.8	423.9	110.9	13.7	13	1.5
IT231173	2	8067	77.1	166.9	204.9	25.4	42.1	.	108.5	13.4	13.2	1.7
IT231173	3	10244	93.2	187.9	186.2	35.3	47	.	121.8	15.4	13.1	1.6
IT231173	4	8402	81.9	168.8	.	.	.	.	124.2	15.6	13.1	1.5
IT231173	5	10256	92	176.3	.	.	.	.	105.6	13.5	13.5	1.4
IT231173	6	10398	96	180.9	.	.	.	.	108.6	13.7	13.6	1.6
IT231179	1	6487	67.1	159.9	168.4	22.9	49.7	434.2	144.6	18	9.7	3.9
IT231179	2	6974.5	70.4	153.2	173	15	52.4	.	144.3	18.3	9.6	3.6
IT231179	3	6776.2	67.9	150.4	146.2	28.6	39	.	140.6	17.2	10	4.3
IT231179	4	5856.2	66.9	135.7	.	.	.	.	140.1	17.3	10	4.1
IT231179	5	5811.8	63.3	142.1	.	.	.	.	146.6	17.9	10	4.2
IT231179	6	6802.8	74.6	147.3	.	.	.	.	150.9	17.7	10.4	4.6
IT231186	1	5297.7	62.4	133.1	203.4	18.7	46.7	119.4	37.6	12.1	4.1	2.1
IT231186	2	4036.1	61.2	98.1	126.4	14.7	45.8	.	41.2	12.2	4.4	2
IT231186	3	4325.9	54.9	117.1	201.3	22.1	40.4	.	45.2	12.5	4.5	1.5
IT231186	4	3849.3	63.2	89.8	.	.	.	.	38.7	12.3	4.1	1.6
IT231186	5	5338.2	69	112.5	.	.	.	.	39.8	12.3	4.3	1.6
IT231186	6	5620.2	64.4	138.2	.	.	.	.	47.3	13.3	5	1.6
IT231187	1	4389.3	53.4	123.5	177.4	19	37.7	103.6	41.3	11.1	5	1.4
IT231187	2	4203.2	55.2	114.6	220.3	19.5	36.2	.	35.9	11	4.1	1.1
IT231187	3	4906.3	61	126.8	176.1	18.7	47.2	.	36.8	11.3	4.1	1.1
IT231187	4	3074.3	56.2	79.9	.	.	.	.	38.8	11.3	4.4	1
IT231187	5	4609.8	52.9	136.2	.	.	.	.	35.4	10.1	4.5	1.3
IT231187	6	5510.3	63.6	138.6	.	.	.	.	33.3	10.3	4.1	1.2
IT231393	1	3124.6	48.1	103	196.8	24.9	52.1	365.2	122.2	30.1	9.3	1.7
IT231393	2	2901.5	48.4	96.2	223.4	29.9	47.3	.	117.6	30.1	7.1	1.4
IT231393	3	3381.5	50.6	109.8	222.1	18.5	50.8	.	92.6	28	7.6	1.4
IT231393	4	3116.7	49.8	103.4	.	.	.	.	93	28.4	7.9	1.6
IT231393	5	3698.6	52.1	114.8	.	.	.	.	123.1	31.5	8.9	1.8
IT231393	6	3767.2	53.8	110.9	.	.	.	.	126.2	31.5	6.9	1.6
IT235610	1	5100.5	65.3	122.4	168.3	17.2	48	709.5	424.3	28.6	17.9	5.4
IT235610	2	3709.3	52.3	108.6	157.4	25	54.1	.	438.6	29.1	17.9	4.9
IT235610	3	3985.2	61.7	112.5	161.9	20.5	35	.	480.3	32	18.9	4
IT235610	4	3952.5	57.6	117.4	.	.	.	.	495.5	34.7	18.9	4.4
IT235610	5	4843.6	64.1	123.8	.	.	.	.	543.9	35	20.7	3.9
IT235610	6	4518.5	58.4	122.2	.	.	.	.	535.1	33.9	20.7	3.4
IT235611	1	4980.2	64.3	124.4	173.8	23	52.5	430.9	33.2	7.2	5.8	1.8
IT235611	2	5008.4	65.7	125.6	172.8	16.4	46.7	.	32.8	7.1	6.5	1.9
IT235611	3	6409.8	73	137.4	151	19.7	42.2	.	33.5	7.1	6.4	1.9
IT235611	4	4996.6	65.6	125.7	.	.	.	.	33.1	6.9	6.4	2.2
IT235611	5	5390.7	68.2	134.7	.	.	.	.	37.4	7.3	7.1	1.9
IT235611	6	4963.3	65.4	123	.	.	.	.	35.9	7.2	6.8	2
IT235612	1	5699.6	65.2	148.8	177.3	22	56.5	492.5	83.6	16.5	8.1	1.7
IT235612	2	6232.5	67.7	151.1	220.4	17.4	61	.	82	16.6	8.1	1.6

APPENDIX- II. *Capsicum annuum*

APPENDIX- II. *Capsicum. Annuum* (continued)

ID	Rep.	Leaf area	Leaf width	Leaf length	Stem length	Stem thickness	Stem angle	Flower area	Fruit area	Fruit length	Fruit width	Fruit thickness
IT235612	3	5343.1	62.7	136.4	178.5	23.3	61.1	.	66	14.9	8.4	1.4
IT235612	4	5292.2	63.7	133.7	.	.	.	.	65.6	15.2	6.9	1.3
IT235612	5	4718.4	60.6	125.4	.	.	.	.	78.5	17	6	1.2
IT235612	6	6200.7	72.9	137.6	.	.	.	.	80.2	16.9	6.1	1.3
IT235613	1	3365.2	49.7	110.2	159.5	18.8	30.2	285.4	89.6	22.1	6	1.4
IT235613	2	3163.2	51.7	104.4	204.7	18.5	44.7	.	85.9	21.7	6	1.7
IT235613	3	3353.2	51.5	112.6	153.3	23.7	45.8	.	89.1	24.2	5.3	1.3
IT235613	4	3087.4	46	107.1	.	.	.	.	88.7	23.5	6.4	1.5
IT235613	5	3581.4	45.9	131.4	.	.	.	.	86.9	21.4	7.7	1.7
IT235613	6	3675.7	49.6	120.9	.	.	.	.	83.9	21.5	6.7	1.4
IT235614	1	4134.1	53	128.6	206.2	17.6	65.6	598.7	137.3	24.5	8	1.4
IT235614	2	3537.7	51.2	114.5	191	19.3	44.5	.	135.9	24.9	7.8	2.5
IT235614	3	3716.5	54.9	111.8	219.2	15.7	48.4	.	125.4	24.3	8	2
IT235614	4	3325.5	50.6	110.8	.	.	.	.	128	24.5	7.4	2
IT235614	5	4686.1	61.4	124.3	.	.	.	.	139.2	24.3	9.4	2.2
IT235614	6	3584	53.7	109.4	.	.	.	.	121.8	24.4	6.9	2.3
IT235615	1	5841	63.5	153.2	598.9	24.2	100.1	337.3	50.7	10.1	6.8	1.5
IT235615	2	6446	71.6	151.6	535.7	23.4	94.2	.	48.5	9.8	6.6	1.2
IT235615	3	5477.9	68.6	138.5	526.4	18.8	104.2	.	44.9	8.4	7.1	1.7
IT235615	4	5137.4	61.2	140.9	.	.	.	.	44.3	8.4	6.9	1.7
IT235615	5	6409	70.7	157.9	.	.	.	.	48.8	9.5	7.1	1.6
IT235615	6	5706.2	67.4	141.3	.	.	.	.	46.9	9.1	6.9	1.5
IT235616	1	6988.2	83.9	143.4	302	17.9	50.3	358.8	187	27.7	10.3	1.7
IT235616	2	6399.3	76.8	142.4	295.4	16.4	54.2	.	181	27.5	9.8	1.7
IT235616	3	6479.4	83.9	131	256.4	16.6	60.5	.	173.3	29.5	9.1	1.6
IT235616	4	5287.7	66.6	134.1	.	.	.	.	171	29.4	8.3	1.5
IT235616	5	6020.4	72.8	146.1	.	.	.	.	158.8	26.9	9.3	1.6
IT235616	6	6990.7	82.4	139.2	.	.	.	.	154.1	27	8.9	2
IT235618	1	5095.2	64.4	139.3	232.1	24.5	48.9	511.5	162.1	29.4	10.5	1.8
IT235618	2	5285.7	65.9	130	195.1	16.4	80.6	.	162.1	30	9.2	1.7
IT235618	3	4938.8	63.5	133.3	198.3	15.4	57	.	160.1	27	10.2	1.6
IT235618	4	4820.7	62.6	132.2	.	.	.	.	156.9	27.2	8.5	1.8
IT235618	5	6094	70.4	144.6	.	.	.	.	182.2	29.7	9.7	1.5
IT235618	6	5597.7	71.6	133.3	.	.	.	.	162.6	29.7	8.5	1.6
IT235661	1	5217.3	65.1	124.1	143.2	13.8	66.5	236.2	194.6	32.2	9.6	2.3
IT235661	2	5067.1	65.9	120.4	182.4	17.9	60.9	.	200.5	32	10	2.3
IT235661	3	5561.2	62.9	134.9	187	19.2	43.6	.	201.7	29.4	9.1	1.8
IT235661	4	4985.7	63.6	121.6	.	.	.	.	219.4	30.2	9.2	1.9
IT235661	5	5059.7	62.4	129.4	.	.	.	.	184.2	26.6	10.6	1.8
IT235661	6	4963	60.6	123.3	.	.	.	.	206.5	27.6	10.4	1.9
IT235664	1	7578.7	79.7	154.9	223.7	18	75.8	590.8	305.8	20.8	19.8	5.7
IT235664	2	6165.3	73.8	131.3	189.7	19	42.5	.	305.2	21.4	19.6	5.3
IT235664	3	6295.5	70.1	137.3	196	21	65.9	.	295.3	21.5	16.9	4.8
IT235664	4	6748.8	71.8	150.4	.	.	.	.	302.2	21.5	17.2	5.2
IT235664	5	6866.5	74.2	143.3	.	.	.	.	265.7	18.6	18.5	5.2

APPENDIX- II. *Capsicum annuum*

APPENDIX- II. *Capsicum. Annuum* (continued)

ID	Rep.	Leaf area	Leaf width	Leaf length	Stem length	Stem thickness	Stem angle	Flower area	Fruit area	Fruit length	Fruit width	Fruit thickness
IT235664	6	8166.9	87.2	155.9	.	.	.	.	281.6	19.4	18.8	4.8
IT235865	1	5892.9	64.4	139.3	178	17.2	42.6	445.3	134.7	25.2	8	2.7
IT235865	2	4653.6	58.7	126.4	181.6	15.2	39.9	.	136.9	25.7	7.5	2.3
IT235865	3	4018.1	52.8	116.8	184.9	17	41.8	.	154.4	28.8	8.1	1.8
IT235865	4	3323.4	49.3	103.7	.	.	.	.	163.2	29.1	8.5	2
IT235865	5	4738.6	59.4	123.3	.	.	.	.	176.6	31.1	8.5	2.5
IT235865	6	4805.4	59.1	124.8	.	.	.	.	166	31.2	7.9	2.2
IT235870	1	6625	71.6	144.3	193.1	14.5	66	378.5	163.9	31.2	7.5	2.7
IT235870	2	5530.3	66.5	132.2	220.1	12.3	89.5	.	162.8	30.8	7.5	2.9
IT235870	3	5418.5	66.3	130.7	225.3	13.5	81.4	.	170.1	29.3	8.4	2.6
IT235870	4	4186	55.5	120.9	.	.	.	.	164.7	29.2	8.3	2.6
IT235870	5	5080.1	64.9	124.5	.	.	.	.	186.9	31.9	10.2	2.9
IT235870	6	5815.1	69.2	132.2	.	.	.	.	182.2	31.3	10.5	2.9
IT235872	1	5757.5	65.6	136.1	203.7	17.7	44.7	385.9	321.3	51.3	15.7	3.2
IT235872	2	5465.8	68.8	125.5	196.4	14.1	46.1	.	357	51.4	16.4	3.3
IT235872	3	6069.9	64.3	145.1	198.4	13.8	62.1	.	248.9	38.8	10.2	3.2
IT235872	4	5737.5	62.9	139.9	.	.	.	.	224.1	39	9.4	2.6
IT235872	5	6050.1	69.9	132.4	.	.	.	.	232.1	42.5	10	2.4
IT235872	6	5084.8	60.8	130.7	.	.	.	.	231.1	42.4	10	2.2
IT235874	1	9459.5	97.2	154.3	216	19.7	71	381.8	527.5	39	17.3	4.3
IT235874	2	9652.9	86.7	174.7	212	19.2	70.5	.	529.3	39.5	17.5	4.1
IT235874	3	14568	110.9	214.7	206.9	19.8	90.4	.	511.8	37.1	18.4	4.6
IT235874	4	11181	93.9	189.4	.	.	.	.	512	37	18.3	4.1
IT235874	5	10054	104.5	146.8	.	.	.	.	579.8	40.5	17.8	4.5
IT235874	6	10957	95.1	174.2	.	.	.	.	582.5	40.9	18	4.4
IT235875	1	10631	95.5	169.6	252	16.4	66	494.6	629.5	39.5	22.1	5.2
IT235875	2	9525.8	85.1	179.8	248.1	15.6	62.9	.	627.1	38.9	22.2	5.9
IT235875	3	8986.3	94.7	157.8	244.8	18.3	68.1	.	615.8	41.6	20	6.5
IT235875	4	9545.9	95.3	167.4	.	.	.	.	604.8	41.2	19.6	6.3
IT235875	5	11844	100.6	184.5	.	.	.	.	678.6	43.8	21.6	5.9
IT235875	6	.	.	.	.	.	.	.	673.9	42.8	22.1	6.3
IT235877	1	10918	98.5	185.3	276.9	18.8	71.3	609.7	888.3	50	24.6	6.3
IT235877	2	10616	106.6	168.6	271	17	72.5	.	867.5	49.8	24.3	5.6
IT235877	3	9926.9	91.7	169.1	215.3	18.7	45.9	.	542.8	43.7	16.9	5.7
IT235877	4	10531	105.1	159.2	.	.	.	.	522.8	42.3	16.5	5.8
IT235877	5	9114.4	95.1	157.1	.	.	.	.	818.2	49.6	22.2	6
IT235877	6	11598	106.5	172.7	.	.	.	.	830.5	50.1	22	5.7
IT235878	1	6206.1	63.7	151.5	257.9	23	70.7	424.9	309.4	26.8	14.7	4.4
IT235878	2	6282.4	68.1	148.4	228.2	13.6	56.8	.	320.1	26.7	15.4	4.7
IT235878	3	5417	62.7	141.7	249.5	14	74.7	.	320.6	29	16	5.1
IT235878	4	6779.3	74.9	141.1	.	.	.	.	322.4	29.3	16.1	4.3
IT235878	5	6471.1	73.1	145.9	.	.	.	.	383	36.4	14.9	4.6
IT235878	6	7497.2	76.8	153.7	.	.	.	.	390.2	36.4	15.3	4.5
IT235914	1	9871.8	95.8	161.5	192.1	17.9	71.1	594.7	563.2	47	17.1	4.3
IT235914	2	10707	100.1	188.1	240.9	17.8	61.2	.	532.9	45.6	17.5	3.5

APPENDIX- II. *Capsicum annuum*

APPENDIX- II. *Capsicum. Annuum* (continued)

ID	Rep.	Leaf area	Leaf width	Leaf length	Stem length	Stem thickness	Stem angle	Flower area	Fruit area	Fruit length	Fruit width	Fruit thickness
IT235914	3	8182.7	83.1	160.9	200.2	18.8	45.3	.	458.6	36.9	17.8	6.1
IT235914	4	8356.4	82.8	147.8	.	.	.	.	459	36.6	17.9	4.3
IT235914	5	13484	111.1	196.5	.	.	.	.	502.5	41.7	17.2	4.8
IT235914	6	9951.2	92.4	169.3	.	.	.	.	503.5	41.9	16.8	4.1
IT235915	1	4272	52.2	132.5	201.3	15	53	329.4	242.8	23.6	14.8	4.2
IT235915	2	4472.4	58.1	129.7	244.7	15.8	65.9	.	243.3	23	14.7	4.1
IT235915	3	4277.6	50	134.4	194.1	18.4	49.8	.	284	27.6	14.5	4.8
IT235915	4	2994.8	45.3	107.6	.	.	.	.	279.7	27.3	14.4	4.4
IT235915	5	4144.5	55.1	121.9	.	.	.	.	214.2	23.7	12.6	3.9
IT235915	6	3804.4	50.6	120.1	.	.	.	.	208.3	23.6	12.5	4
IT235921	1	6442	73.3	138.9	282.4	15.6	69.7	388.8	95	12.7	9.7	5.6
IT235921	2	5699.4	66.7	134.1	273.4	19	72.8	.	89.9	12.3	9	5.3
IT235921	3	6783.8	75.5	136.3	303.1	17.3	32.5	.	89.2	12.2	10.2	5.5
IT235921	4	7257.3	76.8	143.3	.	.	.	.	90.8	12.5	9.1	5.2
IT235921	5	8714.6	81	165.1	.	.	.	.	97.6	12.8	10.2	5.4
IT235921	6	.	.	.	.	.	.	.	87.9	12	10	5.2
IT236215	1	7312.8	86.3	133.7	271	18.2	41.1	201.9	68.9	19.2	4.6	1.8
IT236215	2	7662.6	87.7	143.6	233.4	23.6	48.8	.	66.7	19.6	4.6	1.5
IT236215	3	6466.1	77.2	143.9	271.6	16.3	57.5	.	74.8	20.4	4.8	1.8
IT236215	4	5501.9	69.9	130.9	.	.	.	.	77.8	20.6	4.7	1.6
IT236215	5	6632.6	78.8	147.1	.	.	.	.	68.1	20	4.3	1.5
IT236215	6	8418.8	95.1	144	.	.	.	.	76.7	20.2	4.9	1.4
IT236255	1	9579.8	90	162.8	321.6	17.4	59.1	708.9	522.1	39.8	17.4	3.5
IT236255	2	9501.5	87.8	173.5	288.8	19.8	50.3	.	506.5	38.8	17.1	3.9
IT236255	3	10058	98.8	162.5	309	18.9	51.8	.	531.1	39	17.4	3.2
IT236255	4	8508.1	84.2	161.3	.	.	.	.	528.3	39.6	17.1	2.4
IT236255	5	7895.8	77.7	155.9	.	.	.	.	541.2	38	18.9	2.7
IT236255	6	9009.3	79.2	173.9	.	.	.	.	545.8	36.7	19.4	3
IT236272	1	7728.7	76.3	153.9	131.2	26.8	62	434.6	375.6	22.3	20.7	5.2
IT236272	2	6853.1	70.6	146.3	160.2	19.9	57.1	.	365.6	24.1	19.4	5.2
IT236272	3	7553.1	71.9	160	130.7	24.5	70.3	.	296.3	19.9	19.3	3.9
IT236272	4	7682.7	77.8	153.9	.	.	.	.	294.8	20.5	19	3.8
IT236272	5	8242.2	81.7	158.9	.	.	.	.	328.7	22	19.3	5.3
IT236272	6	7641.9	80.5	151.4	.	.	.	.	329.8	21.9	19.6	4.7
IT236273	1	9783.7	89	181.2	230.3	17.6	70.9	450.9	544.5	28	23.9	5.8
IT236273	2	8503.2	82.8	164.2	208.2	17.9	42	.	546.2	29.3	23.5	6.4
IT236273	3	6985.4	79.4	139.8	.	.	.	.	445.1	27	20.9	4.6
IT236273	4	6464.1	70.3	144.7	.	.	.	.	452.2	26.5	21.1	5.1
IT236273	5	6659.9	74.1	145.4	.	.	.	.	459.5	28.3	20.8	4.5
IT236273	6	7713.9	75.9	168.5	.	.	.	.	440.6	26.5	21	4.7
IT236288	1	5904	69.1	140.3	310.6	17.4	59.4	380.6	162.4	35.6	6	1.6
IT236288	2	7551.5	73.4	163.2	220.6	20.1	51.9	.	150	35.7	5.4	1.5
IT236288	3	5968.5	67.6	142.6	273.4	24.1	44.9	.	133.4	29.1	7.1	1.7
IT236288	4	6428.7	69.5	139.7	.	.	.	.	128.8	28.8	8.2	1.7
IT236288	5	5894.8	65.5	156.5	.	.	.	.	155.7	31.9	8.6	1.9

APPENDIX- II. *Capsicum annuum*

APPENDIX- II. *Capsicum. Annuum* (continued)

ID	Rep.	Leaf area	Leaf width	Leaf length	Stem length	Stem thickness	Stem angle	Flower area	Fruit area	Fruit length	Fruit width	Fruit thickness
IT236288	6	6963.9	67.5	164.4	.	.	.	.	162.7	32.9	6.5	1.9
IT236293	1	8426.7	88.8	149.9	412.2	19.7	62.1	331	355.2	43.6	10.3	2.4
IT236293	2	7397	79.5	147.9	326.7	21.9	82.3	.	387.6	43.3	12.6	2.1
IT236293	3	7204.2	78.4	146.6	397.6	16.5	60.4	.	433.3	49.5	11.7	2.4
IT236293	4	6720.5	78.7	138.1	.	.	.	.	478	47.2	13.9	2.7
IT236293	5	9453.8	93.3	158.5	.	.	.	.	219	37.5	14.1	1.8
IT236293	6	7394.7	77.4	148.3	.	.	.	.	265.4	36.1	15.9	2.1
IT236295	1	3066.4	51.7	89.6	185.3	15	45.9	253.2	26.8	10.3	3.8	0.8
IT236295	2	2105.7	43.8	75.4	138.5	16.9	59.6	.	27.6	10.2	4.1	0.7
IT236295	3	2102.8	41.8	81.1	142	22.4	56.9	.	26.3	11.2	3.4	0.8
IT236295	4	3075.3	50.7	90	.	.	.	.	25.5	11.2	3.5	0.8
IT236295	5	3349.7	55.4	92	.	.	.	.	23.3	10.3	3.4	0.7
IT236295	6	3247.4	49.9	100.3	.	.	.	.	21.8	10.3	3.1	0.6
IT236312	1	6110.3	70.8	137.3	202.7	17.6	50	507.8	313.8	25.6	16.2	4.8
IT236312	2	8372	84.4	151.7	163	22.1	73.4	.	301.1	25.1	15.4	4.3
IT236312	3	7149.3	72.3	146.8	190.6	36.2	66.7	.	300.3	24.4	15.8	3.7
IT236312	4	7884.1	87.9	138.6	.	.	.	.	297.9	24	15.8	3.8
IT236312	5	8920.8	91.2	145.7	.	.	.	.	312.3	27.6	15.4	3.5
IT236312	6	7745	82.3	141.7	.	.	.	.	297.8	27.6	14.7	3.9
IT236313	1	4065.4	58.6	121.5	259.3	15.7	64.7	300.1	76.3	29.5	3.9	1
IT236313	2	4308.4	60.9	114.7	262.4	15.6	65.8	.	71.2	29.4	3.9	1.1
IT236313	3	4861.5	61.7	129.2	218.2	17.2	59.1	.	73.5	30.6	5	1.2
IT236313	4	3982.6	54.5	115.1	.	.	.	.	71.7	30.3	4.5	1.2
IT236313	5	4457	60.6	122.1	.	.	.	.	73.7	29.3	5	1.1
IT236313	6	3127.1	48.6	107.3	.	.	.	.	77.9	29.3	4.4	1.2
IT236333	1	2906.9	45.1	106.2	270.9	22.6	42.3	393.1	106.6	27.2	5.9	1.5
IT236333	2	4445.9	60.5	124.1	303.8	19.8	66.6	.	120.7	28	5.3	1.6
IT236333	3	3341.7	46.6	118.6	239.1	18.3	83.7	.	95.1	25.1	5.4	1.5
IT236333	4	2625	41.5	102.4	.	.	.	.	99	25.1	5.4	1.6
IT236333	5	3956.3	53.6	121.9	.	.	.	.	91.2	25.5	5	1.4
IT236333	6	3150.8	46.7	107.1	.	.	.	.	100.9	26	5.4	1.3
IT236334	1	5692.1	58.6	157.3	261.4	21.5	49.5	369	125.9	24.1	7.8	1.8
IT236334	2	6246.3	70.2	142.1	256.1	17.6	76.2	.	112.8	23.2	6.7	1.7
IT236334	3	5453.1	59.3	152.5	286.5	17.3	74.9	.	116.4	26.9	7.6	1.8
IT236334	4	4927.3	63.1	129.2	.	.	.	.	118.9	27.5	6.9	1.7
IT236334	5	4945.5	62.8	123.3	.	.	.	.	107.4	23.5	7.7	2
IT236334	6	4708.6	57	130.7	.	.	.	.	107.9	23.5	6.3	1.8
IT236336	1	2078.2	40.1	88.3	187.4	20.4	39.3	329.7	94	23.6	5.4	1.7
IT236336	2	1231.7	30.7	67.6	150	25	52.5	.	99	22.6	6	1.4
IT236336	3	1900.4	37.4	84.4	187.1	17	45.5	.	89.6	23	5.5	1.1
IT236336	4	1613.8	35.2	74.9	.	.	.	.	83.6	23.5	5.4	1
IT236336	5	3265	51.4	101.9	.	.	.	.	91.1	21.5	6.3	1.4
IT236336	6	1442.7	35.5	68.1	.	.	.	.	89.3	22	6	1.5
IT236337	1	3471.1	53.1	101.1	207.4	19.6	40.4	347.1	129.4	24.5	7.4	1.9
IT236337	2	3534.6	54.7	102.9	214.1	14.4	57.6	.	121.5	23.9	6.8	1.8

APPENDIX- II. *Capsicum annuum*

APPENDIX- II. *Capsicum. Annuum* (continued)

ID	Rep.	Leaf area	Leaf width	Leaf length	Stem length	Stem thickness	Stem angle	Flower area	Fruit area	Fruit length	Fruit width	Fruit thickness
IT236337	3	3190.8	49.3	97.3	184.5	18.2	52.2	.	112.1	24.2	6.7	1.9
IT236337	4	2557.6	47.9	85.8	.	.	.	.	114.4	23.3	6.8	1.8
IT236337	5	3984.3	57.7	105.2	.	.	.	.	116.9	26.6	6	1.4
IT236337	6	3689.4	54.4	101.6	.	.	.	.	117.1	26.3	6.8	1.7
IT236339	1	7887.2	80.8	157.9	251.6	17.7	69.6	383.6	316.4	42.3	11.8	4.1
IT236339	2	6765.3	72.9	147.6	242.4	17	70.4	.	363.5	41.9	11.8	4
IT236339	3	5228.5	59.1	137.8	230.2	19.3	45.1	.	457.2	41.8	14.1	3.5
IT236339	4	10384	95.1	175.8	.	.	.	.	445.3	41.5	14	4
IT236339	5	8672	90.9	157.2	.	.	.	.	565.9	49.5	15.1	3.4
IT236339	6	7997.5	77.1	177.7	.	.	.	.	546.9	50	14.7	3.5
IT236343	1	11216	99.4	187.5	256.2	20.7	65.9	331.6	576	56.6	18.1	3.5
IT236343	2	10718	90.5	192.7	312.9	19.8	75.3	.	520.5	55.5	18.6	3.5
IT236343	3	7722.7	86.1	141.8	283.2	27	61.2	.	536.9	61.1	12.3	2.5
IT236343	4	9919.2	84.8	193.6	.	.	.	.	519.7	57.3	16	2.5
IT236343	5	12038	97.8	202.4	.	.	.	.	609.5	62.9	13.9	2.8
IT236343	6	8794.7	95.9	143.6	.	.	.	.	601.2	61.4	14.3	2.6
IT236345	1	5941.8	66.9	140.8	177.6	18.3	62.5	387.2	269.5	37.1	21.4	2.3
IT236345	2	6001.9	70.5	139.7	190.5	20.9	62.9	.	261	36.4	19.8	2.4
IT236345	3	8517.5	80.7	161.4	.	.	.	.	239	37.8	10.2	2.4
IT236345	4	6472.4	71.9	147.5	.	.	.	.	226.3	37.4	9.8	2.1
IT236345	5	7814.7	77.7	159.5	.	.	.	.	199.2	38.9	10.4	2
IT236345	6	.	.	.	.	.	.	.	201.4	39	10.2	2.3
IT236346	1	5842.5	70.6	133.2	183	16.7	42.6	429.9	158.7	21.5	10.2	3.1
IT236346	2	7315.9	77.3	145	183.8	22.3	37.9	.	156	21.3	10.2	2.8
IT236346	3	7296.9	71.4	166.8	168	18.9	87.8	.	168.5	22.4	10.4	2.4
IT236346	4	6816.6	71.8	144.4	.	.	.	.	168.7	22.3	10.1	2.7
IT236346	5	6673.2	73.5	148	.	.	.	.	166.4	21.2	10.6	2.8
IT236346	6	7113.7	78.2	144.7	.	.	.	.	166.3	20.9	10.7	2.7
IT236347	1	8147.4	75.1	166.6	184.4	20.8	60.4	527.4	171.1	19.7	10.8	4.7
IT236347	2	5333	59	142.4	182.1	20.1	58.4	.	170.8	19.6	10.9	4.9
IT236347	3	6474.4	66.7	153.2	194.8	20.4	47.9	.	142.9	18	10	4.4
IT236347	4	9196.5	82.8	171.7	.	.	.	.	142.4	17.8	9.9	4.5
IT236347	5	4844.7	54.6	141.4	.	.	.	.	148.3	17.8	10.2	5.5
IT236347	6	9248	82.1	183	.	.	.	.	147.6	17.7	10.2	5.2
IT236348	1	5809.9	65.6	137.9	159.1	19.7	52.1	498.8	177.1	24	10.3	3.8
IT236348	2	7078.8	67.6	160.4	150	15.1	49.7	.	179.2	23.6	10.5	3.5
IT236348	3	6789.9	70.1	158.2	165.4	19.9	40.2	.	157.2	21.8	9.1	3.8
IT236348	4	8965.5	81.7	182.7	.	.	.	.	154.1	21.9	9.1	3.3
IT236348	5	7131.5	70.1	170.5	.	.	.	.	149.8	20.9	9.6	3.5
IT236348	6	6266.9	65.5	155	.	.	.	.	146.2	21.4	9.7	3.6
IT236349	1	5735.5	61.6	141.6	190.6	17.9	78.3	321.5	387.1	28.8	16.5	4.5
IT236349	2	6616.7	76.7	138.1	225.3	29.5	53.6	.	386.2	30.4	16.6	4.4
IT236349	3	9074.8	91.2	160.5	159.3	23.1	49.8	.	354.3	27.4	17.8	4.6
IT236349	4	6970.6	73.4	147.9	.	.	.	.	363.8	27.7	17.9	4.6
IT236349	5	6731.5	67.4	148.3	.	.	.	.	340	27.2	16	3.7

APPENDIX- II. *Capsicum annuum*

APPENDIX- II. *Capsicum. Annuum* (continued)

ID	Rep.	Leaf area	Leaf width	Leaf length	Stem length	Stem thickness	Stem angle	Flower area	Fruit area	Fruit length	Fruit width	Fruit thickness
IT236349	6	4834	64.3	119.2	.	.	.	.	348.6	27.6	16.5	3.9
IT236350	1	11019	98	177.4	251.6	26.4	50	524.2	545.8	45.6	16	4.1
IT236350	2	9380.1	86.2	183.2	237.3	21.3	50.7	.	569.9	45.5	18.1	4
IT236350	3	11402	97.3	183.1	251.6	20	62.2	.	546.5	47.3	17.9	4.1
IT236350	4	12636	93.9	203.9	.	.	.	.	493.5	48.2	13.6	3.8
IT236350	5	12441	95.8	212.7	.	.	.	.	542.7	45.5	17.1	3.9
IT236350	6	10784	90.5	179.6	.	.	.	.	527.3	45	16.7	4.2
IT236351	1	6489.1	73.1	141.9	276	17.1	56.5	299.4	412.1	49.7	11.4	2.5
IT236351	2	5016.3	69.4	119	285	16.2	93.1	.	436.1	50	13.5	2.8
IT236351	3	6187.4	74	131.4	286.5	17	50.2	.	434.1	53.9	10.6	3
IT236351	4	6964.9	74.1	147.6	.	.	.	.	450.1	54.1	11	3
IT236351	5	5374.9	66.1	132.9	.	.	.	.	396.1	54.3	11.3	2.5
IT236351	6	5066.6	65.2	125.4	.	.	.	.	391.4	53	9.9	2.5
IT236352	1	4872.5	63.6	128.5	278.9	18.3	69.7	345.7	506.9	58.4	15	2.5
IT236352	2	4217.2	52.7	134.2	255.2	15.2	46.2	.	502.9	55.1	16.3	2.6
IT236352	3	3351.6	50.6	108.3	267.9	17.5	48.1	.	476	57.3	11.7	2.4
IT236352	4	4977.1	64.1	134.6	.	.	.	.	487.3	52.5	13.3	2.6
IT236352	5	4808.8	60.6	127.2	.	.	.	.	551	62.7	12.4	2.8
IT236352	6	3942.1	55.2	112.5	.	.	.	.	506.3	60.1	12.2	2.7
IT236356	1	4015.3	51.5	125.2	269.9	18	44.7	420.7	297.1	38.4	13.1	3.2
IT236356	2	5230.7	58.8	138.3	229.9	15.1	50	.	287.9	38.9	11.6	3
IT236356	3	5125.3	55	145.6	235.1	16.3	78.5	.	223.9	38.9	8.4	2.2
IT236356	4	4911.3	57.7	134.6	.	.	.	.	225.3	39.6	8.3	2.1
IT236356	5	4134.7	54.9	124.7	.	.	.	.	299.1	44.5	10.2	3
IT236356	6	3879.3	51.1	127.5	.	.	.	.	275.8	44.1	9.2	2.5
IT236357	1	7483.9	70.2	166.3	232.6	17	38.8	346.3	224.5	41.6	6.7	2.7
IT236357	2	4747.5	48	144.9	169.2	17.2	69.3	.	235.7	42.6	7	2.7
IT236357	3	4096.1	49.8	126.1	270.8	15.6	66.8	.	217.3	40.8	8.3	2.7
IT236357	4	6242	56.3	172.8	.	.	.	.	214.3	41.4	7.8	2.4
IT236357	5	6684.9	72.1	147.1	.	.	.	.	189.4	40.2	6.3	2.3
IT236357	6	7702.9	71.4	174.1	.	.	.	.	188.2	39.8	7.8	2.1
IT236360	1	4120.7	54.3	129.9	274	20.9	53.4	356.7	169.9	45.8	7.1	2
IT236360	2	3385.3	46.4	119.2	218.2	26.7	48.8	.	168.1	46.8	7.2	2.1
IT236360	3	3740.4	48.9	126.4	253.3	23.1	33	.	147.5	44.3	5.1	1.9
IT236360	4	2809.1	43.3	106.5	.	.	.	.	149.6	44.5	5.8	2
IT236360	5	3132.3	43.8	112.1	.	.	.	.	154.7	44.4	5.3	1.9
IT236360	6	4245.8	51.5	133.4	.	.	.	.	165.9	44	6	2.1
IT236361	1	4350.6	51.3	133.2	215.1	18.6	63.2	255.1	174.7	40.9	11.5	2.1
IT236361	2	5421	58.8	156.7	191.7	29	37.3	.	168.7	41.7	9.9	1.9
IT236361	3	4349.3	52.1	146.9	190	27.6	56.2	.	193.1	43.7	6.7	2.1
IT236361	4	4697.9	53.9	148.1	.	.	.	.	191.3	43.6	8.8	2.2
IT236361	5	4895.7	56.4	147.4	.	.	.	.	188.2	45.3	9.4	1.8
IT236361	6	4608.1	48.4	148.7	.	.	.	.	179.5	44.5	9.6	1.9
IT236363	1	7269.9	73.9	157.8	252.3	17.8	62.4	333.8	150	36.9	5.5	2.2
IT236363	2	4546.7	57.4	132.4	259.8	16.6	83	.	140.3	37.1	5.2	1.9

APPENDIX- II. *Capsicum annuum*

APPENDIX- II. *Capsicum. Annuum* (continued)

ID	Rep.	Leaf area	Leaf width	Leaf length	Stem length	Stem thickness	Stem angle	Flower area	Fruit area	Fruit length	Fruit width	Fruit thickness
IT236363	3	7117.6	75.1	154.9	272.7	18.5	47.6	.	117.1	36.4	6.9	1.6
IT236363	4	4884.9	60.8	121.5	.	.	.	.	114	36.6	5	1.7
IT236363	5	5694.6	65.2	136.7	.	.	.	.	156.6	38.5	6.2	1.9
IT236363	6	5674.2	68.9	134.8	.	.	.	.	142.1	39.4	6	1.6
IT236364	1	3277.7	42.5	125.7	251.8	25	58.2	287.9	193.1	37.3	6.5	1.6
IT236364	2	2774	41.9	105.4	263.2	16.3	83.6	.	165.1	37.3	6.1	1.6
IT236364	3	2867.4	38.1	125.3	267.9	16.4	57.9	.	203.3	38.9	6.8	1.4
IT236364	4	2382.4	36.6	111	.	.	.	.	202.4	38.4	7.6	1.4
IT236364	5	3101.2	44.4	115.4	.	.	.	.	174	37.6	6.5	1.5
IT236364	6	2964	37.4	125.2	.	.	.	.	184.3	38	6.5	1.7
IT236365	1	4578.1	53.1	158.9	323.6	22.5	57.4	337.2	123.5	33.1	6.9	1.6
IT236365	2	3191	44.5	119.2	289.4	18.1	87.4	.	119.1	33.2	5.8	1.7
IT236365	3	4488.3	55.2	128.6	294.3	19.3	71.7	.	159.9	44.9	6.8	1.8
IT236365	4	3200.1	48	108.2	.	.	.	.	164.3	44.1	7.6	1.7
IT236365	5	5189.7	63.9	129.8	.	.	.	.	133.7	35.7	7.4	2.2
IT236365	6	3711.1	52.9	112.4	.	.	.	.	142.6	36.6	6.5	2.2
IT236366	1	4497.4	51.6	145.2	211	13.4	47.2	410.5	133.9	38.7	5.7	1.6
IT236366	2	7277.1	67.9	172.9	210.6	13.2	44.1	.	127.6	37.9	4.7	1.6
IT236366	3	5462.6	58.4	156.5	254.3	16.7	75.9	.	177.4	49.9	6.9	1.9
IT236366	4	5381.2	58.8	145.4	.	.	.	.	183.2	49.9	6.9	1.8
IT236366	5	5700	63.8	149.4	.	.	.	.	166.8	44.6	13.6	1.9
IT236366	6	5377.1	53.5	155.3	.	.	.	.	161.7	43.2	14.1	2
IT236367	1	4329.4	51.5	134.2	267	17.8	59.5	304.6	125.2	33	5.6	1.7
IT236367	2	3771.7	47.6	136.6	262.7	17.7	49.8	.	121.7	32.2	6.7	1.6
IT236367	3	3107.1	42.1	119.6	260.4	17.4	67	.	140.8	36.1	5.8	1.8
IT236367	4	2465.6	37.2	105.5	.	.	.	.	133.8	35.3	5.1	1.7
IT236367	5	5415.7	56.7	157.3	.	.	.	.	112.9	33.3	7.4	1.5
IT236367	6	3581.2	47.1	122.1	.	.	.	.	118.2	34	5.3	1.7
IT236371	1	3611.5	49.7	113	208.6	22.1	61.8	347.9	156.1	28.4	7.2	1.9
IT236371	2	5153.6	61.7	132.9	226.5	26.4	56.1	.	121.8	28.6	6.5	1.7
IT236371	3	5278.6	64.8	135.7	257.9	21.4	69.4	.	136.5	28.4	8.5	1.5
IT236371	4	3890.5	47.9	125.3	.	.	.	.	130.9	28.8	6.5	1.6
IT236371	5	4954.4	58.9	136.6	.	.	.	.	147	30.4	7.4	1.4
IT236371	6	3651.3	51.9	113.8	.	.	.	.	150.8	30.6	6.6	1.4
IT236373	1	6022	63.8	154.9	200.8	15.5	40.1	305.3	264.1	42.8	8	3.5
IT236373	2	4757.3	60.7	127.4	155.9	17.9	46.7	.	288.9	43.7	9.2	2.7
IT236373	3	3600.5	49.6	109.7	198.6	19.3	53.4	.	244.2	40.9	8.2	2.6
IT236373	4	3570.3	46.4	114.9	.	.	.	.	232.3	41.2	7.4	2.5
IT236373	5	5691	68.4	139.9	.	.	.	.	235.9	38.9	8	3
IT236373	6	4603.7	59.4	114.9	.	.	.	.	250.1	40	7.7	2.7
IT236374	1	4011.9	50.5	132.7	232.9	25.2	51.3	322.1	66.8	39.8	6.3	0.9
IT236374	2	3523.2	44.5	131.3	224	21.9	46	.	68.3	39.2	8.4	1
IT236374	3	4933.9	59.2	137.1	238	18.7	69.4	.	64.9	37.9	4.1	1
IT236374	4	4267.1	56.5	126.9	.	.	.	.	66.3	37.6	2.9	1
IT236374	5	4852.2	55.4	140.5	.	.	.	.	66.5	38.7	4.7	1

APPENDIX- II. *Capsicum annuum*

APPENDIX- II. *Capsicum. Annuum* (continued)

ID	Rep.	Leaf area	Leaf width	Leaf length	Stem length	Stem thickness	Stem angle	Flower area	Fruit area	Fruit length	Fruit width	Fruit thickness
IT236374	6	4728.1	57.3	137.1	.	.	.	.	73.9	41.2	5.6	1
IT236377	1	2440.9	41.1	95.5	316.5	18.4	60.5	284.6	197.9	44.2	7.4	1.8
IT236377	2	1887.9	33.7	91.8	309.1	16.8	58.2	.	186.9	44.7	6.2	1.7
IT236377	3	2800.4	40	107.4	272.7	18.2	58.7	.	189.2	39	13.1	2.1
IT236377	4	2465.1	41.6	95.2	.	.	.	.	173.5	38.4	13.3	1.9
IT236377	5	2961.8	42.6	111.5	.	.	.	.	171.3	39.6	10.2	1.8
IT236377	6	2207.6	40	91.8	.	.	.	.	177.6	40	10.1	1.7
IT236385	1	2936.2	49.3	96.4	246	15.8	85.3	321.6	149.4	37.6	5.8	1.6
IT236385	2	3344	57.9	98	250.3	17.3	62	.	127.1	36.6	5.1	1.5
IT236385	3	3782	55	116.5	191.4	22.1	92.4	.	145.8	36.1	6.1	1.8
IT236385	4	2924.7	48.6	92.6	.	.	.	.	138.1	36.4	6.2	1.9
IT236385	5	3568.6	55.4	104.3	.	.	.	.	107.8	33.6	5.1	1.2
IT236385	6	2608.4	47.4	87.2	.	.	.	.	101.6	34.2	5.6	1.3
IT236386	1	3582.9	49.8	125.7	219.1	19.2	54.2	225.7	97.7	31	4.6	1.2
IT236386	2	1892.1	32.3	96.3	192.4	24.1	35.9	.	95	31.5	4.2	1.3
IT236386	3	3741.5	47.4	133.6	197.1	18.3	53.9	.	87.7	27.8	4.7	1.1
IT236386	4	3349.5	47.2	118.5	.	.	.	.	98.9	28.6	5.4	1.3
IT236386	5	2697.6	43.5	105.7	.	.	.	.	86.6	31.6	4.9	1.2
IT236386	6	3347.3	47.1	120.4	.	.	.	.	96.7	32.1	8.1	1.1
IT236387	1	3754.6	50.8	120.6	260	18.5	79.5	266.7	102.6	34.2	4.4	0.9
IT236387	2	4163.1	53.7	127.4	285	17.7	53.1	.	107.6	34.7	6.4	0.9
IT236387	3	4268.1	52.8	135.8	277.3	15.9	53	.	103.3	34.8	4.6	0.9
IT236387	4	4520	55.8	140.8	.	.	.	.	115.5	35.9	4.8	1
IT236387	5	6873.8	61.9	182.1	.	.	.	.	96.1	31.3	7.1	1.1
IT236387	6	4447.8	53.1	134.7	.	.	.	.	100	31.2	6.1	1.1
IT236390	1	4655.5	56	140.1	339.8	17.3	65.1	221.2	64.7	22.3	5	1.1
IT236390	2	5081.2	59.8	143.7	318.7	19.2	43.6	.	61.1	22.5	4.4	1.1
IT236390	3	6349.5	57.3	183.3	317.1	18	77.9	.	57.3	24.8	4.3	1.1
IT236390	4	5693.8	61.8	154.1	.	.	.	.	62.1	25.1	4	1
IT236390	5	4919.3	53.7	150.9	.	.	.	.	47.6	23.2	3	0.9
IT236390	6	4871.1	55.2	145.3	.	.	.	.	47.1	23	2.9	0.7
IT236392	1	7903.4	75.3	167.2	357.6	22.6	62.5	312.4	141.1	29.1	6.6	1.8
IT236392	2	9108.8	81.8	176.3	275	25	58.6	.	134.8	29.6	6.7	1.6
IT236392	3	6991.7	68.4	159.3	341.5	20.1	48.8	.	146.8	29.4	7.2	2.1
IT236392	4	6073.8	63.4	153.1	.	.	.	.	151.4	29.1	7.6	1.8
IT236392	5	6579.1	67.9	162.9	.	.	.	.	119.2	27.9	7	1.9
IT236392	6	8014.7	73	169.7	.	.	.	.	130.5	30	6.9	1.8
IT236394	1	4012.3	54.3	117.3	216.3	17.9	50.5	242.8	187	38.1	7.9	1.6
IT236394	2	3236.5	47.4	106.7	237.2	19.3	54.2	.	193	39.8	7.6	1.4
IT236394	3	3352.6	48.2	105.8	237.1	17	44.8	.	194.3	37.8	7.8	1.2
IT236394	4	2858.3	45.1	100.9	.	.	.	.	176.1	39.6	6.5	1.1
IT236394	5	4549.3	56.8	129.6	.	.	.	.	166.5	38.8	6.5	1.2
IT236394	6	4307.2	57.4	123.2	.	.	.	.	178.7	39.7	7.1	1.4
IT236395	1	7048.7	64.2	182.7	387.1	21.5	85.5	264	82.6	26.5	4.7	1
IT236395	2	6561.5	63.9	168.3	290.5	21.7	64.8	.	83.1	26.2	5.5	1.1

APPENDIX- II. *Capsicum annuum*

APPENDIX- II. *Capsicum. Annuum* (continued)

ID	Rep.	Leaf area	Leaf width	Leaf length	Stem length	Stem thickness	Stem angle	Flower area	Fruit area	Fruit length	Fruit width	Fruit thickness
IT236395	3	6085.7	66.5	155.2	389.9	23.2	75.9	.	71.3	27.1	5.3	0.9
IT236395	4	5568.3	59.3	153.6	.	.	.	.	68	27.4	4.4	0.8
IT236395	5	4330.5	57.8	124.5	.	.	.	.	78.8	23.1	4.7	0.9
IT236395	6	6521.7	68.5	168.7	.	.	.	.	70.1	23.1	4.1	0.8
IT236396	1	3220.4	47.6	109.9	162.9	18.8	35.6	252.4	43.2	23	4.8	0.7
IT236396	2	3513.9	49.4	114.6	.	.	.	.	45.5	23.1	3.6	0.8
IT236396	3	3128.9	44.6	109.3	.	.	.	.	51.1	22.6	3.5	0.6
IT236396	4	2459.7	40.2	102.3	.	.	.	.	50.8	22.5	3.7	0.7
IT236396	5	3398.9	48.7	117.7	.	.	.	.	51.2	24.1	3.1	0.7
IT236396	6	3969.7	53.3	125	.	.	.	.	49.5	24.3	3.3	0.7
IT236397	1	3203.6	47.3	110.4	284.2	18.5	55.8	327.8	120	30.2	5.1	0.9
IT236397	2	2878.9	45.3	102.1	273.4	16.7	44.4	.	128.1	30.2	5.4	0.9
IT236397	3	3690.9	45.1	135.7	284.9	17.3	80.4	.	126.1	28.4	5.8	1
IT236397	4	3439.5	46	125.1	.	.	.	.	128.8	28.6	5.7	0.9
IT236397	5	4566.2	54.7	140.2	.	.	.	.	115.9	30.4	5.1	1
IT236397	6	3859.8	52.3	126.3	.	.	.	.	120.9	30.4	5.1	1
IT236400	1	5289.3	57.9	145.8	275.2	22.5	54.3	345.6	167.6	32.8	7.2	1.7
IT236400	2	4135.5	52.7	126.8	364.7	22.1	54.7	.	144.6	32.2	6.4	1.6
IT236400	3	4091.8	49	135.1	306.3	25.1	62.1	.	155	31.1	8.1	1.5
IT236400	4	3972.4	51.6	126.1	.	.	.	.	164.2	31.8	8.6	1.6
IT236400	5	7369.2	73.3	161.2	.	.	.	.	148.4	35.2	7.1	1.6
IT236400	6	5745.7	65.9	144	.	.	.	.	155.2	35.4	7.2	1.8
IT236401	1	3873	51.5	124.9	205.7	19.6	51.8	234.9	49.8	24	4.4	1.1
IT236401	2	3046	47.5	109.2	242.6	24.2	50.1	.	48.6	22.7	3.7	1.1
IT236401	3	2365.5	36.4	105.4	182.9	19.4	46.2	.	44.7	21.1	4.7	1
IT236401	4	2050.6	37.1	89.8	.	.	.	.	43.8	21.5	4.3	0.8
IT236401	5	2880.7	42.9	114.3	.	.	.	.	43.8	20.6	5	1
IT236401	6	2753.2	40.8	110.6	.	.	.	.	42.7	20.6	3.6	0.9
IT236402	1	4440.6	55.7	141.1	270.7	22.5	42.8	264.5	78.3	34.7	4.4	0.9
IT236402	2	4856	61.4	140	273.5	20.1	50.9	.	94.7	33.8	5.9	0.9
IT236402	3	4861.1	58.5	139.7	228.2	19.8	68.5	.	55.6	26.8	5.5	0.7
IT236402	4	4094.7	50.6	125.3	.	.	.	.	59.8	26.3	3.7	0.7
IT236402	5	6097.9	58.1	168.8	.	.	.	.	96	33.3	4.3	1
IT236402	6	5838.1	62.5	159.4	.	.	.	.	98	33.3	4.4	1.2
IT236403	1	6254.6	68.5	153.1	287.2	26.5	65.5	283.8	41.1	16.7	3.9	0.9
IT236403	2	6784.6	66.8	168.6	354.4	20.1	51.9	.	39.2	17	3.5	1
IT236403	3	7190.2	70.5	160.4	318.6	34.4	72	.	41.8	17.1	5.9	1
IT236403	4	6948.8	69.8	159.4	.	.	.	.	34.4	16.5	4.8	1
IT236403	5	8105.6	76.7	176	.	.	.	.	36.7	17.2	3.9	0.9
IT236403	6	7480.9	68.6	181.1	.	.	.	.	38.7	16.2	6.6	1
IT236405	1	3545	49.9	110.4	179.4	22.2	16.6	295.9	200.7	36.2	7.9	1.8
IT236405	2	3391.3	46.9	111.4	162.8	26.6	45.1	.	198.7	36.4	7.9	1.4
IT236405	3	2691	45.6	101.5	187	21.9	53.1	.	196.2	35.3	7.5	1.6
IT236405	4	2859.4	48.6	98.8	.	.	.	.	199.5	35.6	7.4	1.8
IT236405	5	3715.1	50.4	112.9	.	.	.	.	193.2	32.7	8.2	1.6

APPENDIX- II. *Capsicum annuum*

APPENDIX- II. *Capsicum. Annuum* (continued)

ID	Rep.	Leaf area	Leaf width	Leaf length	Stem length	Stem thickness	Stem angle	Flower area	Fruit area	Fruit length	Fruit width	Fruit thickness
IT236405	6	3687.3	50.2	111.2	.	.	.	.	194.1	32.4	8.6	1.6
IT236408	1	5946.3	64.8	146.7	319.9	20.4	47.5	248.7	92.4	34	7.4	1.4
IT236408	2	7417.5	70.1	171.8	296.6	17.7	44.9	.	86.8	32.4	4.8	1.1
IT236408	3	5142	56.8	142.7	322.1	18.5	56.7	.	93.7	33.6	6.9	1.1
IT236408	4	5599.9	61.1	140.8	.	.	.	.	89.4	34	8.4	1.2
IT236408	5	5776.7	61.4	146.1	.	.	.	.	85.8	28.8	11	1.3
IT236408	6	6891.6	69.1	161.2	.	.	.	.	84.7	27.5	6.9	1.1
IT236409	1	2065	36.2	91.2	303	16.4	54.1	238.1	41.8	21.7	5	1.1
IT236409	2	1490.8	29.4	90.3	319.7	29	58.5	.	38.1	21.7	4.1	1
IT236409	3	1596.9	28.9	90.5	279.7	21.9	40.7	.	54.8	25.5	7.2	1.3
IT236409	4	1455.9	28.4	84.1	.	.	.	.	54.3	26	6.5	1.1
IT236409	5	1918.9	32.1	95.6	.	.	.	.	37.7	22.1	4.2	1.1
IT236409	6	2337.5	38.6	102.2	.	.	.	.	40.1	22.2	3.3	0.9
IT236410	1	2079.4	38.9	90.2	259.9	24.7	20.1	282.8	52	21.6	4.7	1.3
IT236410	2	1781.2	33.6	90.8	232.1	24.4	79.1	.	56.7	22.3	4.9	1.1
IT236410	3	2643.6	42.5	101.3	261	17.2	82.4	.	39.7	22.7	4.1	1
IT236410	4	2027.5	35.9	90.8	.	.	.	.	46.6	23.3	3.7	0.8
IT236410	5	2584.7	42	106.1	.	.	.	.	51.8	24.1	3.3	1
IT236410	6	2539.3	41.3	101.8	.	.	.	.	54.4	24.2	3.6	1.1
IT236412	1	4744.6	56.1	137.1	327.3	23.3	41.1	254.2	108.3	36.8	4.4	1.6
IT236412	2	4005.2	53.5	127.4	303	21.3	52.8	.	91.2	36.6	3.5	1.4
IT236412	3	2281.7	37.1	100.7	266.4	18.9	44.6	.	124.4	36.9	7.4	1.5
IT236412	4	2446.8	36.4	105.4	.	.	.	.	133.2	37.4	6.6	1.6
IT236412	5	4074.6	51.9	127.3	.	.	.	.	123.9	41.2	6.7	1.3
IT236412	6	3598.1	47.3	122.4	.	.	.	.	131.8	40.8	5.8	1.3
IT236413	1	4423.5	48.8	161.6	265.3	26.6	48	384.4	145.6	38.7	6.4	1.5
IT236413	2	4615.4	50.6	150.8	258.6	21.4	58.6	.	149.5	38.9	6.9	1.6
IT236413	3	3306.4	44.8	127	256.4	18.5	37.4	.	147.5	38.4	8	1.5
IT236413	4	3310.5	44	125.3	.	.	.	.	159.3	40.2	7.4	1.3
IT236413	5	5329.9	55.9	165.8	.	.	.	.	123.5	35.3	5.7	1.3
IT236413	6	4095.7	51.2	137.4	.	.	.	.	126.3	35.9	6.3	1.4
IT236414	1	2828.4	44.3	106.3	204.5	24.2	69.9	215.1	83.4	32.2	3.6	1.1
IT236414	2	3033.9	45.5	109.3	164.7	19	51.6	.	76.3	32.7	4.1	1
IT236414	3	2427.8	43.2	95.5	228.8	19.7	61.2	.	97.1	32.2	6.6	1.1
IT236414	4	1947.8	40.6	77.8	.	.	.	.	92.6	31.7	7.3	1.1
IT236414	5	3298.6	48.4	105.4	.	.	.	.	98.2	31.4	5.7	1
IT236414	6	3304.9	46.8	111.3	.	.	.	.	103.8	31.8	6.6	1
IT236417	1	6329.3	66.8	159.9	307.6	27.9	66.3	241.6	190.6	35.3	8.3	1.6
IT236417	2	4589.5	55.7	136.1	337.8	22.7	52.3	.	176.1	35.1	9.6	1.7
IT236417	3	4963.5	58.9	136.5	286.1	22	74.3	.	209.1	36.2	8.1	1.8
IT236417	4	4874.4	61.2	128.9	.	.	.	.	185	35.9	7.5	1.2
IT236417	5	4426.6	59	129.9	.	.	.	.	165.6	35.4	6.5	1.3
IT236417	6	4444.8	61	114.6	.	.	.	.	221.5	36.7	8.3	1.5
IT236420	1	5555.9	68.2	135.5	228.4	15.6	36.8	252.7	553.2	25.8	25.8	5.1
IT236420	2	6678.6	69.2	152.1	214.6	15.8	51.1	.	534.3	26.4	25.1	4.7

APPENDIX- II. *Capsicum annuum*

APPENDIX- II. *Capsicum. Annuum* (continued)

ID	Rep.	Leaf area	Leaf width	Leaf length	Stem length	Stem thickness	Stem angle	Flower area	Fruit area	Fruit length	Fruit width	Fruit thickness
IT236420	3	4821	61.3	123.3	218.1	18.3	42.9	.	495.9	27.4	23	5.1
IT236420	4	4450.9	65.2	112.8	.	.	.	.	498.8	27.8	23.1	4.3
IT236420	5	5506	68.7	129.3	.	.	.	.	556.9	26.3	26.1	6
IT236420	6	6121.8	68.4	140.7	.	.	.	.	558.5	26.7	25.9	5.8
IT236423	1	2365.6	39.8	100.4	170.9	15.4	52.4	305	140.2	32.2	7.5	1.7
IT236423	2	2157.7	35.7	103.1	165	13.6	54	.	140.3	31.9	8.4	1.3
IT236423	3	1481.5	29.6	85.2	164	17	52.9	.	142.2	35.4	7.8	1.4
IT236423	4	1424.6	28.4	79.3	.	.	.	.	145.8	35	7.3	1.6
IT236423	5	1931.1	33.9	96.1	.	.	.	.	142.9	34.2	6.9	1.4
IT236423	6	1873.5	35.9	88.3	.	.	.	.	159.5	33.4	7.9	1.4
IT236425	1	3810.7	53.9	112.2	164.3	23.8	53.3	250.3	69.6	16.4	6	1.4
IT236425	2	3362.5	50.3	102.5	182.2	33	44.5	.	61.5	18.3	4.9	1.4
IT236425	3	2938.3	55.9	86.3	.	.	.	.	54.9	15.9	5.4	1.5
IT236425	4	2603.2	46.2	89.6	.	.	.	.	54.2	15.8	5.3	1.7
IT236425	5	3822.6	55.8	110	.	.	.	.	48.9	15.5	5.1	1.5
IT236425	6	3133	50.1	91.8	.	.	.	.	47.4	15.3	4.8	1.5
IT236426	1	2132.8	36.5	94.6	119.3	20.2	56.5	272.2	81.4	22.3	5.3	1.3
IT236426	2	2063.4	37.8	90.5	169	18.2	43.4	.	77.9	22.4	4.9	1.4
IT236426	3	2317.9	39.5	100.6	147.4	24.9	63	.	91.6	23.2	5.9	1.3
IT236426	4	2340.8	40.9	96.8	.	.	.	.	93.8	23.6	5.6	1.4
IT236426	5	2783.7	43.6	106.7	.	.	.	.	85.8	23	5.5	1.4
IT236426	6	3435.1	47.8	112.8	.	.	.	.	85	23.3	6	1.4
IT236427	1	4716.9	64	110.8	185.5	18.1	83.3	197.5	72.9	18.8	5.2	1.5
IT236427	2	4061.2	60.3	105.2	289.7	20.5	48.7	.	75.3	19	5.3	1.2
IT236427	3	3432.9	53.2	103.3	260	19.6	61.6	.	61	17.5	5	1.2
IT236427	4	3605.9	53.3	108.5	.	.	.	.	65.4	17.4	4.8	1.3
IT236427	5	6009.3	67.6	147.8	.	.	.	.	70.3	18.3	5	1.3
IT236427	6	3361.4	49.9	110.6	.	.	.	.	73.2	18.1	5.6	1.5
IT236428	1	4987.2	65.2	126.6	273.3	19.8	69.9	383.9	177.8	30.4	7.9	2.7
IT236428	2	3926.5	55.4	114.4	291.9	15.1	61.2	.	196.4	30.5	8.8	2.7
IT236428	3	5455.2	66.4	132.7	336.7	18.3	52.6	.	196.3	30.5	8.2	2.6
IT236428	4	4902.2	67	123.8	.	.	.	.	206.5	30.9	9.2	2.7
IT236428	5	4409.1	57.8	120.4	.	.	.	.	170.4	29.9	7.6	2.1
IT236428	6	3674.3	50.4	113	.	.	.	.	177.2	29.9	8.1	2.5
IT236429	1	6213.3	68.1	154.6	305.6	19.1	41.9	388.5	149.9	33.9	6.2	1.5
IT236429	2	4814.4	57.5	140.2	342.1	14.9	70.1	.	145	33.1	6.9	1.5
IT236429	3	4511	56.5	132.7	331.3	16.2	47.9	.	155.1	37	8.4	1.9
IT236429	4	5056.4	57.7	133.2	.	.	.	.	187.4	37.9	7.7	1.8
IT236429	5	4712	56.1	139.4	.	.	.	.	148.3	36	11.2	1.6
IT236429	6	4647.5	54.3	141.7	.	.	.	.	171.5	37.7	9.7	1.6
IT236430	1	1980.2	37.9	83.4	174.2	19.4	49.7	263.1	74.4	21.6	4.7	1.2
IT236430	2	2203.7	41.1	86.1	155.9	24.3	49.1	.	77.2	22.1	4.7	1.2
IT236430	3	2034.6	39.7	83.9	171.9	19	45.8	.	82.8	20.4	5.7	1.2
IT236430	4	2012.2	34.8	89.7	.	.	.	.	78.1	20.3	5.2	1.1
IT236430	5	3217.7	49.7	108.6	.	.	.	.	75.6	20.6	5.1	1.2

APPENDIX- II. *Capsicum annuum*

APPENDIX- II. *Capsicum. Annuum* (continued)

ID	Rep.	Leaf area	Leaf width	Leaf length	Stem length	Stem thickness	Stem angle	Flower area	Fruit area	Fruit length	Fruit width	Fruit thickness
IT236430	6	2558.6	45.5	89.7	.	.	.	.	83.3	21	5.5	1.3
IT236431	1	5141.7	60.2	133	309.6	16.8	63	264.9	136.1	30.4	5.9	2.1
IT236431	2	5431.2	59.7	142.9	279.7	16	80.5	.	133.7	30.5	6.5	2
IT236431	3	5327.4	57.5	137.5	328.2	25.9	45.2	.	137.6	31.8	6.2	1.6
IT236431	4	4748.2	53.7	132.8	.	.	.	.	148.3	31.8	6.2	1.7
IT236431	5	6475.8	65.8	153.5	.	.	.	.	122.1	32.5	5.2	1.5
IT236431	6	6072.6	68.1	141.2	.	.	.	.	127.2	32.4	5.4	1.4
IT236432	1	7069.5	71.9	153.8	322	14.8	73.2	264.7	178.6	35.8	7.4	1.5
IT236432	2	6466.9	68.6	150.3	251.8	20.7	63.6	.	189.2	36.3	6.7	1.8
IT236432	3	6574.6	69.7	149.5	303.5	17.8	63.2	.	209.9	39	7.6	2
IT236432	4	4753.4	57.3	132.4	.	.	.	.	224.8	39.1	7.4	1.5
IT236432	5	5578.1	60.9	138.7	.	.	.	.	216.4	38.8	8.2	2.3
IT236432	6	5281.1	63.3	129.6	.	.	.	.	220.3	39.3	8.5	2.5
IT236433	1	6226.4	70.9	138.3	210.3	30.4	51.7	286.1	299.4	21.5	17.3	8.1
IT236433	2	7229.9	79.9	154.1	292.7	25.5	43.4	.	294.8	21.2	17.8	8.5
IT236433	3	5802.7	69.8	136.4	220.1	30.3	44.3	.	295.3	21	18.8	6.9
IT236433	4	6992.4	75.5	145.8	.	.	.	.	285.8	21.3	18.5	6.4
IT236433	5	7881.2	77.8	155.1	.	.	.	.	276.8	19.5	17.2	6.7
IT236433	6	7444.8	84	140.8	.	.	.	.	273.5	19.3	17.1	7.3
IT236434	1	5670.9	64.8	136.9	270.4	12.7	49.4	375.1	102.1	23.7	6	2
IT236434	2	5056.1	64.4	124.7	207.9	15.7	42.5	.	92.1	23.9	5.6	2
IT236434	3	5909.5	70.2	137	287.6	17.9	80	.	110.2	25.5	6.6	2
IT236434	4	6190.2	77.5	127.5	.	.	.	.	98.8	24.4	6.1	1.6
IT236434	5	5729.9	66.8	134.3	.	.	.	.	107.4	24.6	7.8	1.6
IT236434	6	5614	66.5	128.7	.	.	.	.	123	25.3	6.7	1.6
IT236435	1	5756.4	66.1	153.7	220.7	29.5	52.6	291.5	111.8	24.9	5.8	1.7
IT236435	2	4839.1	63.5	118.6	216.5	14.3	46.5	.	107.6	25.6	5.4	1.6
IT236435	3	6248.9	73.1	133.4	239.3	18.5	43.1	.	90.3	22.8	5.6	1.6
IT236435	4	4581.9	60	122.7	.	.	.	.	83.9	23	4.9	1.6
IT236435	5	3974.4	58.1	110.5	.	.	.	.	115.8	25.9	5.6	1.7
IT236435	6	6098.2	74.2	132.7	.	.	.	.	119	25.9	6.3	1.9
IT236436	1	4090.1	50.9	125.1	297.6	17.7	70	339.7	181.8	31.8	7.8	1.9
IT236436	2	3042.2	46.9	106.2	231.3	14.8	55.8	.	174.8	31.5	7.9	1.9
IT236436	3	4294.8	55	129.6	270	21.1	68.6	.	151.9	28.9	8.1	2.8
IT236436	4	3468.5	49.7	106.7	.	.	.	.	146.3	28.8	7	1.8
IT236436	5	4835.5	64.1	122.6	.	.	.	.	170.7	30.5	9.9	1.7
IT236436	6	3964.6	55.4	113.3	.	.	.	.	174.2	31.4	8.3	1.7
IT236448	1	9040.7	90.1	168.4	231.8	27.1	52.3	403.1	554	28.5	26.2	7
IT236448	2	8846.9	89.5	162.3	175.6	21.8	43.7	.	563.2	27.9	27.6	6.2
IT236448	3	8447.9	79.3	160	199.3	22.5	61.6	.	479	25.8	23.4	5.3
IT236448	4	6833.5	72.6	143.8	.	.	.	.	472.6	26.5	22.7	4.9
IT236448	5	8531.6	91.2	161.9	.	.	.	.	491.4	27.2	23.3	6.2
IT236448	6	9858.5	89.5	181.1	.	.	.	.	496.4	27.3	23.9	6.7
IT236449	1	5958.2	73.4	130.2	128.8	16.4	57.2	571.4	446.8	26	22.8	7.1
IT236449	2	4262.9	63.1	112.6	177.5	23.8	37.7	.	451.8	25.6	22.2	6.4

APPENDIX- II. *Capsicum annuum*

APPENDIX- II. *Capsicum. Annuum* (continued)

ID	Rep.	Leaf area	Leaf width	Leaf length	Stem length	Stem thickness	Stem angle	Flower area	Fruit area	Fruit length	Fruit width	Fruit thickness
IT236449	3	6840.1	81	132.9	125.5	22.6	37.8	.	419.5	24.9	24.1	6.2
IT236449	4	7091.3	81.6	134.1	.	.	.	.	431.1	25.1	24.3	7.1
IT236449	5	5613.9	63.9	132.5	.	.	.	.	540.8	27.9	25.9	5.7
IT236449	6	4635.4	58.3	116.1	.	.	.	.	513.9	27.7	24.6	5.6
IT236451	1	9068.9	87.7	159.8	213.6	20.8	55.2	314.6	323.4	25.7	18.4	4
IT236451	2	8324.7	80.5	173.4	228	30	55.4	.	307.5	25.2	17.6	4.3
IT236451	3	8297.4	79.5	169.7	190.6	22.6	44.9	.	373.4	23.1	21.1	3.9
IT236451	4	9117.9	80.5	182.9	.	.	.	.	364.2	22	21.3	3.2
IT236451	5	8129.1	77.8	157.5	.	.	.	.	281	22.5	17.5	3.6
IT236451	6	8436.3	82.2	156.7	.	.	.	.	271.5	22.5	16.9	4.7
IT236453	1	8435.7	78.7	166.4	175	19	64.2	382.7	457.7	38.5	16.4	5.6
IT236453	2	10107	88	175.3	246.7	20.7	46.9	.	439.4	38.2	16.6	5.3
IT236453	3	12369	100.2	193.2	179.2	17.8	54.4	.	499.5	35.6	20.2	6.1
IT236453	4	14150	113.8	185.3	.	.	.	.	489.1	35.4	19.8	6.4
IT236453	5	14628	104.9	213.3	.	.	.	.	489.2	39.3	18.1	4.8
IT236453	6	9215.6	88.5	165.4	.	.	.	.	489.5	39.4	18	4.9
IT236458	1	7977.6	80.6	152.4	154	22.1	106.9	624.3	221.4	17.8	15.8	4.1
IT236458	2	7615.8	83.7	146.1	182.2	13.6	61.8	.	197.6	16.8	15.1	4.6
IT236458	3	9752.5	95.5	154.3	204.2	15.7	46.4	.	266	20.8	16.8	7
IT236458	4	7972.1	77.3	164.7	.	.	.	.	256.7	20.2	16.4	6.6
IT236458	5	6478.6	75.5	133.5	.	.	.	.	218.2	16.7	16.4	6.4
IT236458	6	7988.6	83.5	150.3	.	.	.	.	223.5	17.1	16.9	6
IT236459	1	6851.6	75.5	137.2	192.1	12.9	39.7	409.8	469.9	27	21.8	8.4
IT236459	2	6508.2	75.7	130.2	205.9	12.5	38.9	.	504.6	27.4	22.2	7.6
IT236459	3	4262.6	57	124.7	163.6	13.8	63.3	.	552.3	30.2	22.6	6.2
IT236459	4	4272.5	62	114.4	.	.	.	.	528.7	28.2	23.1	6.4
IT236459	5	5529.1	63.5	134	.	.	.	.	701.1	29.3	28.9	6.3
IT236459	6	5892.9	74.2	125.1	.	.	.	.	679.6	29.5	28.9	5.9
IT236460	1	7832.5	82.7	147.4	144.2	31.6	56.7	313.8	304.9	22.7	17.9	4.8
IT236460	2	6014.5	67.9	143.6	135.9	20.5	58.5	.	322.6	23.9	18	4.1
IT236460	3	5771.1	67.9	130.2	152.9	30.7	51.7	.	334.8	24.3	18.1	4.1
IT236460	4	6560.5	75.5	129.3	.	.	.	.	309.1	23.6	17.7	4.1
IT236460	5	5199.5	67.6	115.3	.	.	.	.	351.9	28	17.1	5.4
IT236460	6	8918.3	89.6	155.4	.	.	.	.	348	28.1	16.7	4.6
IT236465	1	6002.9	66.9	137.6	234.6	18.8	48.1	259.7	109.7	33.7	5.9	1
IT236465	2	5517.3	67.6	129.9	274	16	73.3	.	111.8	32.5	6.4	1.6
IT236465	3	5272.9	64.4	126.1	202	19.4	50.9	.	114.1	33.8	9	0.9
IT236465	4	5019.2	67.1	115.8	.	.	.	.	118.8	33.6	7.4	1.4
IT236465	5	.	.	.	.	.	.	.	86.9	30.8	5.4	1.3
IT236465	6	.	.	.	.	.	.	.	99	31.6	5.1	1.2
IT236466	1	7397.1	75.3	159.8	233.8	14.6	52.3	280.8	108.2	29.1	7.3	1.6
IT236466	2	5509.9	72.7	131.3	286.2	22.9	97.1	.	112.6	29.7	6.9	1.7
IT236466	3	6042.9	66.9	140.8	283.7	17.2	53.5	.	145	32.1	7.3	1.5
IT236466	4	4304.5	58.6	118.3	.	.	.	.	142.8	32.5	6.9	1.8
IT236466	5	7277.8	75.6	159.2	.	.	.	.	139.6	33.7	6.6	1.5

APPENDIX- II. *Capsicum annuum*

APPENDIX- II. *Capsicum. Annuum* (continued)

ID	Rep.	Leaf area	Leaf width	Leaf length	Stem length	Stem thickness	Stem angle	Flower area	Fruit area	Fruit length	Fruit width	Fruit thickness
IT236466	6	5647.4	65.9	131.1	.	.	.	.	145.3	33.5	6.9	1.5
IT236467	1	7071	77.5	144.9	246.4	28.3	51.2	271.1	123.7	32.8	5.7	1.3
IT236467	2	5796.9	70.5	132.8	218.3	15.7	76.1	.	99.7	30.8	5.9	1.2
IT236467	3	7471.8	82	145.7	213.6	19.9	49.1	.	100.2	31.7	5.5	1.3
IT236467	4	7089	71.7	145.9	.	.	.	.	90.7	31.8	4.7	0.9
IT236467	5	7443	78.2	145.3	.	.	.	.	129	31.8	6	1.7
IT236467	6	6228.7	66.8	141.8	.	.	.	.	143.4	32.1	8.1	1.9
IT236468	1	4973.7	61	128.4	200.3	22.3	43.5	237.8	221.9	39.3	10.1	2.2
IT236468	2	4748.9	58.7	128.8	184.1	21.4	40.8	.	205	39.9	7.8	1.8
IT236468	3	6314.6	68.9	141.2	212.4	17.9	53.5	.	154.8	34.9	7.2	1.9
IT236468	4	5750.2	65.3	132.6	.	.	.	.	159.3	36.2	7.4	1.8
IT236468	5	7243.5	81.4	135.2	.	.	.	.	186.3	38.5	11.7	2.2
IT236468	6	4712.7	59.5	120.4	.	.	.	.	175.5	38.3	10.4	2.2
IT236469	1	5612.8	67.8	127.5	212.1	17.7	50.5	172.1	181.5	36.2	7.2	2
IT236469	2	4931.2	63.2	123.7	200.7	14.6	44.7	.	169.6	33.9	7.3	1.7
IT236469	3	4018.8	58.9	107.4	210.3	18.9	43	.	164.7	34.5	6.7	1.8
IT236469	4	3738.5	56.9	103.5	.	.	.	.	167.8	36.7	6.4	2
IT236469	5	5399.4	63.7	126.8	.	.	.	.	180.9	34	9.2	2.5
IT236469	6	4352.3	57.2	123	.	.	.	.	174.2	34.1	7.9	2.3
IT236470	1	4365.3	62.4	110.4	327.1	15.5	46.6	319.8	133.8	29.8	6.9	1.9
IT236470	2	5025.6	63.4	117.7	327.9	17.2	50.4	.	138.1	29.1	6.8	2.1
IT236470	3	4126.4	59.5	106.3	266.3	18.2	63.6	.	146	29.7	7.2	2.1
IT236470	4	4065.5	58.4	108.4	.	.	.	.	139.7	30.1	6.8	2
IT236470	5	4837.6	63.9	115.8	.	.	.	.	142.1	30	8.1	2.3
IT236470	6	4972.2	68.1	117.9	.	.	.	.	143.4	29.7	7.2	2.1
IT236471	1	5249.9	67.3	118.1	241.1	15	47.8	258.8	197.6	38.2	7	2.3
IT236471	2	5189.8	68.5	119.9	229	13.6	54.3	.	187.2	38.3	7.1	2.2
IT236471	3	6525.2	75.8	137.8	243	13.1	87.1	.	206	40.4	6.5	2.5
IT236471	4	4818.7	63.3	118.1	.	.	.	.	206.2	41.2	6.3	1.9
IT236471	5	5177.3	66.8	117.3	.	.	.	.	167.5	35.1	6.3	1.8
IT236471	6	5040.6	64.1	120.3	.	.	.	.	184.2	35.9	7	1.8
IT236532	1	12799	100.2	188.3	272.7	43.7	46.3	461.5	302.5	23.7	15.9	3.9
IT236532	2	11631	91.9	204.2	188.2	34.7	47.5	.	313.7	24.3	16.4	3.2
IT236532	3	9901.5	86.9	179	243	19.8	53.4	.	326.7	22.9	18.5	3.1
IT236532	4	11195	94.6	189.2	.	.	.	.	331	22.9	18.4	4.6
IT236532	5	11496	102.1	177.9	.	.	.	.	341.8	24.2	19.5	5.2
IT236532	6	12226	97.1	196.6	.	.	.	.	339.6	24.5	19.2	5.2
IT236755	1	8325	82.6	161.2	183.9	198.1	42.2	283.6	244.7	20.2	15.6	7.6
IT236755	2	11158	100.8	170.8	215	16.4	68.6	.	247.2	20.5	15.8	5.9
IT236755	3	7424.7	82.4	141.9	197.3	15.9	64.9	.	248.3	20.3	15.1	8.3
IT236755	4	7996.8	77.7	158.2	.	.	.	.	239.1	21.4	14.6	6.6
IT236755	5	7342.1	76.2	153.4	.	.	.	.	255.3	20.9	15.3	7.8
IT236755	6	10408	93.9	176.2	.	.	.	.	240.9	21.2	14.5	6.8
IT236772	1	10675	86.4	189.9	222.1	15	62.2	340.8	208	26	10.5	2.4
IT236772	2	7123.7	65.7	171.4	144.8	22.6	73.6	.	182.4	25.7	9.1	2.5

APPENDIX- II. *Capsicum annuum*

APPENDIX- II. *Capsicum. Annuum* (continued)

ID	Rep.	Leaf area	Leaf width	Leaf length	Stem length	Stem thickness	Stem angle	Flower area	Fruit area	Fruit length	Fruit width	Fruit thickness
IT236772	3	5645.2	55.1	161.4	277.7	21.3	46.9	.	187.1	25.9	9.4	2.5
IT236772	4	4538.1	52.3	138.5	.	.	.	.	181.7	25.5	9.1	2.2
IT236772	5	3933	50.6	119.1	.	.	.	.	187.4	25.4	10	2.5
IT236772	6	11453	88.8	197.2	.	.	.	.	184.3	25.7	9.5	2.1