

**GENETIC VARIABILITY AND PATH COEFFICIENT ANALYSIS FOR
YIELD AND YIELD RELATED TRAITS IN 4 VARIETIES AND 26 AC-
CESSIONS OF HOT PEPPER (*Capsicum annum* L.) CULTIVATED AT
TONY FARM, DIRE DAWA, ETHIOPIA**

M.Sc. THESIS

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Genetic Variability and Path Coefficient Analysis for Yield and Yield Related Traits in 4 Varieties and 26 Accessions of Hot Pepper (*Capsicum Annuum* L.) Cultivated at Tony Farm, Dire Dawa, Ethiopia

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DEDICATION

This piece of work is dedicated to the memory of my late parents.

STATEMENT OF THE AUTHOR

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BIOGRAPHICAL SKETCH

The author was born on August 15, 1993 in Yayo Wereda, Ilubabor Zone of Oromia Region, Ethiopia from his father Bekele Amde and his mother Tsedale Teferi. He attended his elementary and junior secondary education at Yayo and Wutete Elementary School, respectively, from 2001-2008. Then he pursued secondary school education at Metu Abdi Bori High School and finally he attended Preparatory School at Sebeta Secondary and Preparatory School from 2009-2012. After the completion of his preparatory school education, he joined Mekelle University in 2013 and graduated with a B.Sc. degree in Applied Biology in July 2015. Soon after graduation, he was recruited by the Ministry of Education and joined the school of graduate studies at Haramaya University to pursue his M.Sc. Degree in Genetics in September 2015.

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ACRONYMS AND ABBREVIATIONS

ANOVA	Analysis of Variance
AVRDC	Asian Vegetable Research Development Center
CPI	Chili Pepper Institute
CSA	Central Statistical Agency
EARO	Ethiopian Agricultural Research Organization
EEPA	Ethiopian Export Promotion Agency
FAO	Food and Agricultural Organization
GCV	Genotypic Coefficient of Variation
IAR	Institute of Agricultural Research
IBPGR	International Board for Plant Genetic Resources
MARC	Melkasa Agricultural research Center
PCV	Phenotypic Coefficient of Variation
RCBD	Randomized Complete Block Design
SE	Standard Error

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Genetic Variability and Path Coefficient Analysis for Yield and Yield Related Traits in Hot Pepper (*Capsicum annuum* L.) Accessions at Tony Farm, Dire Dawa, Ethiopia

ABSTRACT

*Chili (*Capsicum annuum* L.) is an important spice, an integral part of many cuisines and widely used foods in the world. To assess the magnitude and extent of genetic variability, and association of agronomic traits among some chili accessions and varieties and their contributions to yield, a field experiment was conducted using twenty six accessions and four varieties during the off-season period from November 2016 to May 2017 under irrigation. The experiment was conducted using RCBD design with three replications. The analyses of variances (ANOVA) showed highly significant differences nearly for all traits tested, except fruit girth, pedicel length and plant height. Among the yield components primary branch per plant, dry fruit yield per plot, fruit length, stem width, and number of fruit per plant had high GCV and PCV values along with high heritability and genetic advance as percent of mean. For all traits, phenotypic coefficient of variation was higher than genotypic coefficient of variation, indicating that there was environmental influence on these traits. High heritability along with high genetic advance as percent of mean was observed for primary branch per plant, stem width, fruit length, number of fruit per plant and dry fruit yield per plot. Plant height, primary branch per plot, days to fifty percent flowering, stem width, number of fruit per plant, fruit length, days to maturity and number of fruit per plant were positive and highly significantly correlated with dry fruit yield per plot at both genotypic and phenotypic correlation. Plant height (0.1081), number of fruit per plant (0.2610), fruit length (0.4293), stem width (0.4059), pedicel length (0.0122), days to maturity (0.0401) and internode length (0.0227) exerted positive direct effect on dry fruit yield per plot at phenotypic level. Genotypic path analysis showed that days to fifty percent flowering (0.0956), stem width (0.5867), fruit length (0.3671), plant height (0.0754), number of fruit per plant (0.2673) and internode length (0.0079) had positive direct effect. The direct effect of these characters on dry fruit yield per plot indicates that improvement on these traits may increase yield.*

Key Words: *Capsicum annuum*, Correlations, Direct effect, Genetic advance, Heritability, Indirect Effect

1. INTRODUCTION

Pepper (*Capsicum* sp.) is one of the most varied and widely used foods in the world. From the various colors to the various tastes, peppers are an important spice commodities and an integral part of many cuisines. Peppers originated in the Mexico and Central America regions. Christopher Columbus encountered pepper in 1493 and, because of its pungent fruit, thought it was related to black pepper, *Piper nigrum*, which is actually a different genus. Nevertheless, the name stuck and he introduced the crop to Europe, and it was subsequently spread into Africa and Asia (Kelley and Boyhan, 2009).

Peppers are considered the first spice to have been used by human beings and there is archaeological evidence of pepper and other fossil foods from as early as 6000 years ago (Hill *et al.*, 2013). The genus *Capsicum* contains about 20 species. Now five domesticated species *Capsicum annuum*, *C. frutescens*, *C. chinense*, *C. baccatum*, *C. pubescens* are only recognized. All cultivated species of *Capsicum* have $2n = 24$ chromosomes. Within *C. annuum*, a tremendous range in size, shape and mature color of fruits have been selected that now forms the basis for the types used in commerce throughout the world. All these species of *Capsicum* have many cultivated varieties suited to different agro-climatic conditions (Sarker, 2013).

It is believed that chili was introduced to Ethiopia during 1520 to 1770 by the Portuguese. Today, Ethiopians consume chili in many different forms. Eating chili is a deeply rooted Ethiopian food habit. Nutritionally, chili is rich in vitamins A and C. A large part of the vitamin intake for Ethiopians comes from chili. The daily consumption of chili pepper is about 15 grams per person. In Ethiopia, chili is grown on approximately 246,000 ha, making it the second largest production area in the world. The crop is mainly cultivated on small patches of farmland. The average national yield is 400 kg ha^{-1} of dry fruit (CPI, 1998).

Diverse hot pepper genotypes have been widely grown in tropics and typical tropical climate in Ethiopia over centuries. More than 100,000 tonnes (annual average) of dry fruit of hot pepper are produced in the country and used for export for worldwide market, but a substantial amount is consumed locally as a spice which exceeds the volume of all other spices put together in the country. According to Fekadu *et al.* (2008), there is a serious shortage of dry fruits both for export and local markets partly due to very low productivity (0.4 t dry fruit

yield/ha) of the crop.

Though hot pepper has been cultivated for centuries in typical tropical climate in Ethiopia but the yield has remained very low due to limited improvement work on the crop. However, diverse genotypes (more than 300) of the crop have been introduced from different regions of the world and local collections have also been made in the country. The genetic improvement of hot pepper is also lacking in the country due to non-availability of requisite genetic information (Fekadu *et al.*, 2008).

Data on the level of genetic diversity of a germplasm collection increase the efficiency of efforts to improve a species (Geleta *et al.*, 2005). Diversification of germplasm can be done in various ways; one of the most effective ways is the use of local landraces. A stabilizing selection has allowed the creation of valuable cultivars from local landraces (Herman, 2005). The usefulness of selection depends on the amount of genetic variation present (Adunga and Labuschangne, 2003). To enhance the progress in breeding new varieties of the crop the knowledge and understanding of the genetic basis of economic traits is very crucial (Fekadu *et al.*, 2008).

Any genetic improvement in a crop can be achieved by bringing beneficial and desirable genes in a genotype and discouraging genes that govern undesirable traits. Yield and productivity are the two major desirable attributes (Pandit and Adhikary, 2014). Yield is a complex character and determined by many factors. The variation in yield and quality characters is determined by genetic and environmental factors (Zecevic *et al.*, 2011). But yield components are relatively simple and less affected by the environment. While selecting for yield, improvement of yield contributing traits, which can be better ascertained if the nature and kind of association of such traits with yield is available, must be considered (Kumar *et al.*, 2010).

Knowledge about the degree of association of yield with components and interrelationships among them may prove useful in selection. Simple correlation coefficients provide information regarding association of characters. A better insight into the cause of association is provided by path coefficient analysis, a method of partitioning correlation coefficients into direct and indirect effects of component characters. Correlation of various characters with yield is useful and provides criteria for direct selection of component characters. Partitioning of total

correlation into direct and indirect effects by path analysis helps in making selection more effective (Kumar *et al.*, 2010).

Ethiopia is believed to be one of the centers of diversity of hot pepper due to diversity of the existing germplasm in diverse growing agroecological zones in the country (Abraham *et al.*, 2017). Moreover, the crop is becoming high value cash crop since its demand is extremely growing locally and internationally. Despite its potential, existing variability for improvement works and current demand, only a few research conducted under Ethiopian condition regarding trait association and yield component traits (Abraham *et al.*, 2017). It is well known that exploring the genetic variability of chili in different environmental condition would allow breeders to select for characters and varieties which lead towards better yield by providing required genetic information. So, this study was initiated with the following objectives:

General objective

- ❖ To ascertain the magnitude and extent of genetic variability, and association of agronomic traits among some chili accessions and varieties and their contribution to yield.

Specific objectives

- To estimate the nature and magnitude of genetic variability for yield and yield related traits in chili accessions and varieties.
- To estimate heritability and genetic advance of some agronomic traits in chili peppers.
- To assess the extent of association of traits among themselves and with yield.

2. LITERATURE REVIEW

2.1. Origin, Distribution and Genetic Diversity

Pepper (*Capsicum* sp.) is one of the most varied and widely used foods in the world. From the various colors to the various tastes, peppers are an important spice commodity and an integral part of many cuisines. Peppers originated in the Mexico and Central America regions. Christopher Columbus encountered pepper in 1493 and, because of its pungent fruit, thought it was related to black pepper, *Piper nigrum*, which is actually a different genus. Nevertheless, the name stuck and he introduced the crop to Europe, and it was subsequently spread into Africa and Asia (Kelley and Boyhan, 2009). In spite of this, CPI (2007) reported that Chili peppers originated in the lowlands of Brazil as small red, round, “berrylike” fruits. This location called the ‘nuclear area’ has the greatest number of wild species of chili peppers in the world today.

Scientists believe that birds are mainly responsible for the spread of wild chili peppers out of this ‘nuclear area.’ Over the centuries birds developed a symbiotic relationship with chili peppers. Birds do not have the receptors in their mouths that feel the “heat” and a bird’s digestive system does not harm the chili pepper seed. So while birds could go around gathering up the small fruits and consuming them with no adverse effects, dispersed seeds would grow into new plants. Many scientists also believe that chili pepper plants evolved the capsaicinoids, the chemical that makes chili peppers hot, to deter mammals from eating the pods, thus ensuring the spread and continuation of the species. The fruit of wild chili peppers, when ripe, are easily removed from the plant by birds, however, when green will not pull away from the calyx very easily, thus ensuring that only viable seeds are being dispersed (CPI, 2007).

The study of genetic diversity is the process by which variation among populations is analyzed by a specific method or a combination of methods (Buys *et al.*, 2002). There are several methods to study genetic diversity using morphological, cytological and biochemical markers and more recently through DNA based technologies (Akbar *et al.*, 2010), but knowledge of the phenotype given by morphological and agronomical descriptors is still important (Sudre *et al.*, 2010) for the assessment of genetic diversity and considered as a good source of information for the breeders with the target traits (Yadeta *et al.*, 2011).

The data often involve numerical measurements and in many cases, combinations of different types of variables. Diverse data sets have been used by researchers to analyze the genetic diversity in crop plants; most important among such data sets are pedigree data, morphological data and biochemical data obtained by analysis of isozymes and storage proteins and DNA based marker data (Buys *et al.*, 2002).

2.2. Description of Chili Plant

2.2.1. Taxonomy and classification of chili

All peppers are members of the Solanaceae family, which also includes tomato, tobacco, eggplant and Irish potato (Kelley and Boyhan, 2009). Pepper consist of annual or perennial herbs or shrubs and are predominantly diploid ($2n = 24$; infrequently, $2n = 26$), except a few (Moscone *et al.*, 2003). Cultivated peppers are all members of *Capsicum* species (Bosland and Votava, 2000). There has been much debate amongst botanists and taxonomists as to number and classification of *Capsicum* species; but it is now widely accepted that the genus *Capsicum* consists of five domesticated species and twenty-six wild species (Araceli *et al.*, 2009).

The most common of these is *Capsicum annuum*. A herbaceous annual plant originally from the central part of South America. It is the most important species with sweet and spicy fruits. The most common varieties include *Capsicum abbreviatum* (with small cone shaped fruits that do not grow larger than 5 cm); *Capsicum acuminatum* (with long, thin cone- shaped fruit that are slightly curved); *Capsicum fasciculatum* (with erect fruit, thin and grouped together), *Capsicum cerasiforme* (with small round fruit similar to cherries) and *Capsicum bicolor* (with two toned very small fruit, that's purple, orange and red) (Baral and Bosland, 2002).

Christopher Columbus was the first to describe pepper and subsequently introduced it into Europe in the fifteenth century and other early explorers disseminated it through post voyage route to Africa, India, and the Middle East. Cultivation has spread throughout the world (McMullan and Livsey, 2013). Terms like pepper, chili, chile, chilli, paprika, aji and *Capsicum* are frequently used interchangeably (DeWitt and Bosland, 2009).

Table 1. Taxonomy of chili.

Kingdom	Plantae
Division	Magnoliophyta
Class	Magnoliopsida
Order	Solanales
Family	Solanaceae
Genus	<i>Capsicum</i>
Species	<i>annuum</i>

Source Pawar *et al.* (2011)

2.2.2. Morphological description of pepper

Plant morphology examines the pattern of development, the process by which structures originate and mature as a plant grows (Bäurle and Laux, 2003). Morphological descriptors provide essential information on genotypes by giving correct species identification (Dias *et al.*, 2013). Morphological characterizations serve as a powerful tool in the classification of cultivars as well as study their taxonomic status and a very useful means of bringing to light traits of agronomic importance especially quantitative traits for crop improvement (Geleta *et al.*, 2005).

All natural populations of pepper are diploid and have the same chromosome number, $2n=24$ (Grubben and El Tahir, 2004). Typically, cultivated fruit reaches the mature green stage in 35-50 days after the flower is pollinated. The fruits are characterized as non-climacteric in ripening (Bosland and Votava, 2000). Gómez *et al.* (2013) found that all the *C. annuum* genotypes displayed variation for all the morphological characteristics evaluated. Days to flowering and fruit color at intermediate stage were the variable with minor variation.

2.2.3. Varietal differentiation

Globally due to its economic importance, especially in Asian countries such as Thailand, China, and the Philippines, the Asian Vegetable Research Development Center (AVRDC) had begun the varietal evaluations to develop more productive and adaptive cultivars for the region. Accordingly, the AVRDC has chosen hot pepper as one of its principal crops. Subsequently, with collaboration from the International Board for plant Genetic Resources (IBPGR), at the very beginning was able to have a collection comprising 5,177 accessions from 81 countries/territories (Yamamoto and Nawata, 2005).

In Ethiopia Capsicums has been grown for a long time by local farmers and considered as an indigenous vegetable crop and due to a long period of cultivation in different parts of the country a great deal of natural hybridization has occurred among different capsicum species. As a result many local genotypes have evolved with various plant and fruit characters as well as disease and pest reactions. Research on *capsicum* started with minor observation and mass selection from local materials in different experimental stations of Awasa and Bako (MARC, 2003).

However, later strong research activities on varietal screening and cultural practices were started at Bako Agricultural Research Center. Major activities like varietal screening against diseases, adaptation studies and plant selections have been attempted at Nazret and Jimma Research Centers and at different trial sites in Gambella and farmers' fields in Southern Showa (Mareko, Tedele, Enseno) and Bako area. In the last 30 years, extensive research has been conducted mainly on hot pepper in different research centers and in Ambo plant protection centers and Haramaya University. Some improved cultivars from each type have been developed and some management practices like spacing, sowing date, rate of fertilizer, planting method, seeding rate and disease and pest control measures were recommended (MARC, 2003).

Currently different research activities are also in progress at different centers to alleviate some of the main production constraints and develop better productive varieties from local collections and imported materials. Among the selection work conducted earlier at Bako and Awasa Research Centers two local selections Mareko Fana and Bako Local cultivars were developed by mass selection, since then they are widely grown in different parts of the country. Mareko Fana with larger and pungent pods with highly demanded dark- red color and Bako Local with high pungency content and yield, in which Bako Local was recommended for high rainfall Western part of the country and Bako areas, for Mareko Fana was recommended for Southern and Oromia region and other areas with similar environmental and soil conditions. These cultivars are highly preferred by the local consumers owing to their pungency level, attractive color content and high powder yield and acceptable color. Particularly cultivar Mareko Fana is the only cultivar being used for a long time by the local factories for the extraction of capsicum oleoresin for the export market (MARC, 2003).

Diverse hot pepper genotypes have been widely grown in tropics and typical tropical climate in Ethiopia over centuries. The varietal analysis techniques have been found to be the useful tools to obtain precise information about the types of gene actions involved in the expression of various traits and to predict the performance of the progenies in the latter segregating generations. Each variety has its own significant effect on yield and yield components, and each variety has its own traits that are part and parcel as quality parameters of the crop (shape, size, color, taste and pungency). The most important traits among others include, number of branches per plant (count), plant height, number of fruits per plant, days to maturity (count from days of transplanting), dry fruit yield per plant, fruit length and single fruit weight (Fekadu *et al.*, 2008). Even though about a dozen hot pepper cultivar was released, in Ethiopian pepper research history, two cultivars, namely Mareko fana and Bako local, released in 1976, are being extensively produced in the commercial farms and by the peasant sector (Al-emu and Ermias, 2000).

2.2.4. Production trend of pepper

Hot pepper is the leading vegetable and spice crop grown in Ethiopia (Esayas, 2009). The central (Eastern and Southern Showa), western, northwestern (Wollega and Gojjam) and the southern part of the country are the potential pepper producing areas. Currently, most of the products come from Alaba, Meskanina, Mareko and Siltie Zone, which are situated in southern part of Ethiopia. Birr sheloko and Didessa valleys which are located in Gojjam and Wollega, respectively, also produce a good amount of pepper. Chilli is well adapted in Gambella, Mizan Teferi and Tepi as a rain fed crop and in Gode as an irrigated crop (Rahman *et al.*, 2006). Pepper production accounts for 34% of the total spice production in the three regions of the country, namely Amhara, Oromia and Southern Nations Nationalities and Peoples Regional States (Roukens, 2005).

FAO (2009), indicated that the estimated production of peppers in Ethiopia was 220,791 t from 97,712 ha in green form and 118,514 t of dry pepper from an area of 300,000 ha. According to CSA (2011) report, vegetables took 0.95% of the area covered by crops at a national level and from this, 65.85% of the area was under red peppers. This report also indicated that the area coverage for dry pepper in the country increased from 54,376 to 83,416.06 ha from 2003/04 up to 2010/11 production years. Moreover, the production of dry hot pepper at

the national level in 2010/11 production season was 209,872.12 t with an average productivity of 2.52 t/ha.

2.3. Importance of Pepper

2.3.1. Uses of pepper as food and spice

The importance of any crop lies in the nutritive value derived from its consumption. Like many other horticultural crops, the nutritive attributes of pepper are manifold. The analysis of the chemical composition of chili fruit shows that it contains proteins, carbohydrates, minerals, calcium, magnesium, sodium, potassium, copper, sulfur, chlorine, phosphorus, iron, thiamine, vitamins (ascorbic acid), and pro-vitamins (carotene) (Grubben and El Tahir, 2004). Chili is cultivated primarily for the fruits which are consumed fresh and in dried forms either as salads or as condiments for the preparation of some local dishes. It is the world's major vegetable and spice crop (Zewdie *et al.*, 2004).

The fruit colour is due to the presence of total carotenoids pigment, which mainly consists of capsanthin and capsorubin, and the extent of the coloring matter is important for the spice industries (Kumar *et al.*, 2003). Chili provides a valuable source of nutrition and employment opportunities, especially among the rural women (Onwubuya *et al.*, 2008). The nutritional value of pepper merits special attention, because it is a rich source of vitamin A, C and E. Both hot and sweet peppers contain more vitamin C than any other cultivated vegetable crop (Bosland and Votava, 2000).

Table 2. The nutritional content of chili [per100gm]

Parameters	Chillies Dry	Chillies Green
Moisture	10.000 gm	85.700 gm
Protein	15.000 gm	2.900 gm
Fat	6.200 gm	0.600 gm
Minerals	6.100 gm	1.000 gm
Fibre	30.200 gm	6.800 gm
Carbohydrates	31.600 gm	3.000 gm
Energy	246.000 K cal	29.000K cal
Calcium	160.000 mg	30.000 mg
Phosphorus	370.000 mg	80.000 mg
Iron	2.300 mg	4.400 mg
Carotene	345.000 µg	175.000 µg
Thiamine	0.930 mg	0.190 mg
Riboflavin	0.430 mg	0.300 mg
Niacin	9.500 mg	0.900 mg
Vitamin C	50.000 mg	111.000 mg
Sodium	14.000 mg	–
Potassium	530.000 mg	–
Phytin Phosphorus	71.000 mg	7.000 mg
Magnesium	–	272.000 mg
Copper	–	1.400 mg
Manganese	–	1.380 mg
Molybdenum	–	0.070 mg
Zinc	–	1.780 mg

Source: Pawar *et al.* (2011)

2.3.2. Medicinal importance

The medicinal use of *Capsicum* has a long history dating back to the Mayas who used it for the cure of asthma, coughs and sore throat. Today, several other medicinal values have also been ascribed to pepper including the cure of arthritis, rheumatism, cold, headache and toothache (Sonago, 2003). Capsaicin extract from sweet pepper is used in pharmaceuticals as a counter irritant balm for external application of sore muscle. Creams containing capsaicin have reduced pain associated with post-operative pain for mastectomy patients and for amputees (Grubben and El-Tahir, 2004).

The extract of these indigenous herbs are highly effective in rheumatism, stiff joints, bronchitis and chest colds with cough and headache. It may be used as a cream for the temporary relief of minor aches and pains of muscles and joints associated with arthritis, simple backache, strains and sprains. Improves circulation, aids digestion by stimulating gastric juices, stimulates the appetite, reduces inflammation, is a mild stimulant or tonic, improves metabolism, and stops bleeding from ulcers. It is good for the kidneys, lungs, spleen, pancreas, heart, and stomach (Pawar *et al.*, 2011). Long Pepper is boiled in milk and water and drunk once a day in the early morning. Drinking this decoction reportedly caused cessation of malarial parasite multiplication and regression of splenomegaly (Majeed and Prakash, 2000).

The topical application of capsaicin cream is quite safe and very effective in the treatment of pain ordinarily observed in patients experiencing diabetic neuropathy and diabetic polyneuropathy. Capsaicin has been shown to help prevent cholesterol associated heart diseases such as arteriosclerosis and its more advanced form of atherosclerosis. Capsaicin reduces ventricular tachycardia and ventricular fibrillations. Capsaicin also dramatically improved blood flow to the heart. Capsaicin seems to function as a natural calcium blocker, analogous to the effect of some prescription heart drugs. Capsicum can protect the body against some known food and beverage chemicals that can cause cancer and induce cell mutations (Pawar *et al.*, 2011).

More uses of pepper are embedded in some of the daily consumables. Apart from the nutritional and medicinal values, peppers are also important because they stimulate the mucous membrane of the mouth, stomach and bowels, causing strong peristalsis, and in the process promoting digestion (Grubben and El-Tahir, 2004).

2.4. Genetic Variability, Heritability, and Genetic Advance

2.4.1. Genetic variability

Genetic variability is a measure of the tendency of individual accessions in a population to vary from one another (Burt and Austin, 2000). The success of crop improvement program depends on the extent of genetic variability existing in the population or germplasm with which plant breeder is working (Meena and Bahadur, 2013). The magnitude of genetic variability can determine the pace and quantum of genetic improvement through selection or through hybridization followed by selection (Rathod *et al.*, 2016). The improvement can be brought out after confirming the variability in different characters among different genotypes. The potential for improvement in any crop is proportional to the magnitude of genetic variability present in the germplasm. A wide range of variability is available in chilli due to its ability to cross pollinate, which provides possibilities to improve fruit yield through a breeding program (Maurya *et al.*, 2015).

Khurana *et al.* (2013) observed highly significant variation among the genotypes in terms of fruit yield, fruit length, fruit thickness, and number of fruits per plant. Sreelathakumary and Rajamony (2003) reported that analysis of variance significantly differed for plant height, stem girth, leaf area, leaf petiole length, fruits per plant, fruit length, fruit girth, fruit weight and yield per plant among the accessions. Mishra *et al.* (2004), Mini and Khader (2004), and Sonia *et al.* (2006) found significant differences among genotypes for all traits studied.

Significant variation between the genotypic and phenotypic variances was registered for fresh yield per plant, dry yield per plant, number of fruits per plant, plant height, and number of seeds per fruit (Singh *et al.*, 2005). Mishra *et al.* (2004) found high phenotypic and genotypic coefficients of variation, heritability and genetic gain were observed for ascorbic acid content, number of fruits per plant, fruit yield per plant, seed yield per fruit and fruit length.

The highest values of genotypic (3250.51) and phenotypic variances (3333.35) were recorded for yield per plant. Higher phenotypic and genotypic coefficients of variation (PCV and GCV, respectively) were observed for yield per plant, fruit weight, fruits per plant, fruit length and

fruit girth than for other characters. Days to first flower and node at first flower had the lowest PCV and GCV (Sreelathakumary and Rajamony, 2003).

Shimeles *et al.*, 2016 found wide range of variation in hot pepper and the magnitude of PCV was higher than the magnitude of GCV for most of the characters except for leaf area index and pericarp thickness. The estimates of PCV were the highest for the number of branches followed by dry weight, number of fruits per plant and internode length and fruit yield per plant, pericarp thickness, flowering and fruiting period, leaf area index, plant height and fruit diameter.

2.4.2. Heritability

The heritability estimates provide information on transmission of trait (s) from parents to offspring. Such estimates facilitate the evaluation of genetic and environmental effects, aiding in selection. Estimate of heritability can also be used to predict genetic advance under selection, so that plant breeder can anticipate the improvement of selection (Shaukat *et al.*, 2015). The effectiveness of selection is dependent upon the variability present in the germplasm and the extent to which it is heritable. A character which has higher range of genetic variability, heritability and genetic advance would be an effective tool to improve yield (Aytac and Kinaci, 2009).

Parameters having high heritability and genetic advance are considered under control of additive genes, which highlights the usefulness of selection based on phenotypic performance (Ghosh and Gulati, 2001). Theoretically, heritability can range from one where all variation is due to genetic, to zero where all the variation results from the environment. The actual heritability value will fall somewhere between these extreme values. It is difficult to determine the amount or types of genetic variability if phenotypic expressions are strongly influenced by the environment (Basazen, 2006). Plant canopy, number of fruits per plant, days to 50% fruiting, plant height, days to 50% flowering and pod length showed high heritability (Verma *et al.*, 2004). Shimeles *et al.*, 2016 found high heritability for fruit length, fruit diameter and internode length.

High heritability coupled with high genetic advance was observed for 100-seed weight, fruit length, average fruit weight, number of fruits per plant, green fruit yield per plant, fruiting span and number of secondary branches, indicating that selection based on these traits would be ideal (Mini and Khader, 2004).

High heritability coupled with high genetic advance observed for these characters imply the potential for crop improvement through selection (Sreelathakumary and Rajamony, 2004). Heritability was highest for plant height (98.12%) followed by fruit length (96.74%) and number of fruits per plant (96.18%) (Mohammed *et al.*, 2001). Singh *et al.* (2005) found the highest heritability values for fruit length. Heritability estimates were moderate to high for all characters except the number of primary branches (Dipendra and Gautam, 2002). High estimates of heritability coupled with high genetic advance were also observed for these characters, indicating that these traits can be effectively improved through selection (Manju and Sreelathakumary, 2002).

The highest magnitude of heritability was registered for fruits per plant, fruit length, fruit girth, fruit weight and yield per plant (Sreelathakumary and Rajamony, 2003). Fruit yield, number of fruits per plant, fruit length, fruit diameter, and number of seeds per fruit had high values of heritability (Khurana *et al.*, 2003). The heritability estimates were high for most of the characters (Prabhakaran *et al.*, 2004). High estimates of heritability were also shown by these characters. This indicates that selection can be a better option for improvement in these traits (Sonia *et al.*, 2006).

2.4.3. Genetic advance

Genetic advance is the measure of the expected genetic progress that would be resulted from selecting the best performing accessions being evaluated and improvement in the mean genetic value of the selected plants over the base population for a given character (Prakash, *et al.*, 2003).

The expected genetic advance was high for number of fruits per plant and dry fruit yield per plant (Maurya *et al.*, 2015). Similar finding was also reported earlier by Kumari *et al.* (2010) for number of fruits and dry fruit yield per plant; Datta and Das (2013) for fruit yield per plant.

The highest genetic advance along with high heritability was recorded for fruit drop percentage, followed by fresh fruit yield per plant, dry fruit yield per plant, number of fruits per plant, leaf area index, and fruit length, indicating the importance of these traits in selection for high yield (Dipendra and Gautam, 2002). Prabhakaran *et al.* (2004) found high genetic advance as a percentage of the mean for yield per plant, mean fruit weight, placenta length and capsaicin. The genetic advance was greatest for fresh yield per plant, dry yield per plant, and number of seeds per fruit (Singh *et al.*, 2005). Genetic advance for many characters were high like that of fruits per plant, marketable fruits per plant and fruits per plant (Sonia *et al.*, 2006). High to moderate heritability along with high to moderate genetic advance were observed for pericarp thickness, leaf area index, internode length, number of internodes, and fruit diameter (Shimeles *et al.*, 2016).

2.5. Association of Characters

2.5.1. Correlation coefficient

The progress of selection depends on knowledge of relationships of yield traits and their relative contribution, which is helpful in the effective and simultaneous selection of characters. Knowledge of interrelationships serves two purposes for breeders. First, these are highly useful in selecting characters that are not easily observed or genotypic values that are modified by environmental effects. Morphological characters associated with higher yield or that make a significant contribution to yielding ability would be useful in improvement. Secondly, interrelationships between characters make available information regarding the nature, extent, and direction of selection pressure among characters (Kumar *et al.*, 2010).

Correlation analysis measures the mutual relationship among the fruit characters and determines the component characters on which selection can be used for improvement in yield (Luitel *et al.*, 2013). Correlation, in general, measures the extent and direction (positive or negative) of a relationship occurring between two or more characteristics (Rohman *et al.* 2003). Simple correlation only describes the overall relationship between the two or more characteristics under study, whereas the estimates of genetic and phenotypic correlations describe the extent of genetic and phenotypic factors in establishing a relationship between two plant traits. The estimate of genetic correlation (r_g) refers to the association between two plant

characters due to the genetic constitution of the plant, whereas phenotypic correlation (r_p) refers to the correlation between two plant characters due to their physical appearance at a morphological, anatomical, or biochemical level (Zhang *et al.* 2005).

To determine relationships, correlation analyses are used such that the values of two traits are analyzed on a paired basis, results of which may be either positive or negative. The result of correlation is of great value in the evaluation of the most effective procedures for selection of superior genotypes. When there is a positive association of major yield traits, breeding would be very effective, but when these traits are negatively associated, it would be difficult to exercise simultaneous selection for them in developing a variety (Nemati *et al.*, 2009).

Correlation coefficient indicates whether or not relationships exist between two variables. It is a single summary that gives a good idea about how closely one variable is related to another variable. In plant genetics and breeding studies, correlation is used to determine the relationship between any two types of measurements made on the same individuals. The identification of correlated traits is very crucial for three chief reasons: 1) in connection with the genetic causes of correlation through the pleiotropic action of genes, 2) in connection with the changes brought about by selection, and 3) in connection with natural selection. The first point is important because pleiotropy is the common property of major genes, while the second and third points are important in order to know how improvement of one trait causes simultaneous change in another trait and to understand the relationship between metric traits and fitness (Falconer and Mackay, 1996).

Luitel *et al.* (2013) were undertook correlation analysis for the fruit yield and quality characters in segregating F₂ population of mini-paprika cv. 'Vine sweet-yellow' and 'Vine sweet-orange'. They found that the correlation of fruit number per plant with other studied characters was non-significant. In contrast Fruit weight was highly correlated with fruit length, fruit width, fruit volume and fruit yield per plant in a positive direction. Similarly Fruit length showed highly significant positive association with fruit shape index, fruit volume and fruit yield. Moreover, fruit width showed a highly significant association with fruit yield per plant in a positive direction. Likewise, Fruit number showed strong positive association with fruit yield.

Sasu *et al.* (2013) obtained strong correlation between the fruit weight to fruit length, diameter and also between the number and weight of fruit per plant. Shimeles *et al.* (2016) found that fruit yield per plant showed significant positive associations only with pericarp thickness ($r = 0.91$) and number of fruits per plant ($r = 0.61$), which indicates that these characters are the major components for pepper fruit yield. On the other hand, fruit yield per plant showed significant negative associations with days to flowering ($r = -0.73$) and 50% fruiting period ($r = -0.75$). Canopy width showed a significant positive association with plant and fruit characters except with the number of fruits per plant. Whereas the number of branches had significant positive associations with canopy width and number of fruits per plant, it had a negative association only with fruit diameter and leaf area index. Fruit weight had a significant positive association with the most important yield components like leaf area index, canopy width, pericarp thickness and number of internodes, whereas a significantly high negative association was noted with the number of fruits per plant.

Genotypic correlation showed that fruit yield per plant had significant positive associations with pericarp thickness and number of fruits per plant (Shimeles *et al.*, 2016). Dry fruit yield per plant, showed significant and positive association with plant height, plant spread, number of fruits per plant, fruit girth, seeds fruit and capsanthin content. Negative correlation was observed between number of fruits per plant and fruit shape index and number of seeds per fruit (Kumari *et al.*, 2011). Ajjapplavara *et al.* (2005) found that dry fruit weight had positive correlation with all fruit related traits viz., fruit length, fruit surface area, fruit volume, stalk length, single green fruit weight, ten green fruit weight. Abraham *et al.* (2017) found that hot pepper yield correlated highly significant positive with number of branch per plant, stem width and fruit number per plant.

According to Bijalwan and Mishra (2014) the correlation coefficient at both genotypic and phenotypic levels indicated that fruit yield per plant was significantly and positively correlated with fruit weight at edible maturity, number of fruits per plant, fruit length, number of branches per plant and ascorbic acid content. Negative and significant correlation of fruit yield per plant was observed with days to 50% flowering at both genotypic and phenotypic level.

Vijaya *et al.* (2014) found dry fruit yield per plant had significant positive correlation with the number of fruits per plant followed by number of primary branches per plant and fruit length.

Growth parameters like plant height and plant spread were found to have negative non-significant association with dry chili yield. Number of fruits per plant had significant positive associations with fruit length and significant negative association with fruit diameter.

2.5.2. Path coefficient analysis

Knowledge of correlation alone is often misleading as the correlation observed may not be always true. Two characters may show correlation just because they are correlated with a common third one. In such cases, it becomes necessary to use a method which takes into account the causal relationship between the variables, in addition to the degree of such relationship (Khan and Dar, 2009). Path coefficient analysis is a standardized partial regression analysis and as such measures the direct influence of one variable upon the other and permits separation of correlation into direct and indirect effects (Zhang *et al.* 2005). Partitioning of total correlation into direct and indirect effects provide actual information on contribution of characters and thus form the basis for selection to improve the yield (Khan and Dar, 2009).

Sasu *et al.* (2013) observed that in the bell pepper landraces, fruit weight per plant was mainly influenced by the number of fruits ($P = 1.036$) and fruit weight ($P = 0.571$). Also, number of fruits per plant showed a negative influence on production/plant by fruit diameter, lodge number and fruit weight traits. Moreover, fruit weight had an indirect and positive effect on production/plant, through fruit length and diameter. Abraham *et al.*, 2017 found that plant height, branch number per plant, fruit number per plant and average fruit length exerted positive direct effect where as stem diameter had negative direct effect on yield.

According to Shimeles *et al.* (2016) the direct effect of the flowering period on fruit yield was low and positive and its indirect effect via leaf area index, fruit diameter, number of internodes, and fruit weight was high and positive. The direct effect of the fruiting period on yield was also negative and medium. The direct effect of fruit length on yield was very low and the indirect effects via fruit diameter and pericarp thickness were positive, but the indirect effects on leaf area index, number of internodes and fruit weight were negative. Fruit weight had the highest direct negative effect on fruit yield (-2.8) and also produced a highly indirect negative effect on the number of internodes and leaf area index. Plant height had a high direct negative

effect on fruit yield (-0.4), but its high indirect positive effect was noticed on leaf area index, fruit diameter, canopy width and Internode length.

Kumari *et al.* (2011) found that the number of fruits per plant exhibited highest direct positive effect and indirect effect through other characters like weight of dry stalkless chillies per plant, number of seeds per fruit and capsanthin content, thus increasing an overall genotypic correlation value with dry fruit yield per plant. Days to maturity exhibited a good amount of direct effect on dry fruit yield per plant and its correlation with dry fruit yield was positive.

According to Ajjapplavara *et al.* (2005), the direct effects of ten dry fruit weight were positive and much higher than its genotypic correlation with yield. Its indirect effect through fruit length and fruit diameter were high and positive, indicating that the direct selection for ten dry fruit weight and indirect selection for fruit length and fruit diameter has increased yield. Days to 50 percent flowering showed a negative direct effect on yield though its correlation with yield was much smaller and negative.

Bijalwan and Mishra (2014) reported that number of fruits per plant, fruit weight at edible maturity and fruit length had high positive direct effect on fruit yield per plant at phenotypic and genotypic levels whereas, leaf area, days to 50% flowering, pericarp thickness, dry matter content and ascorbic acid content had high positive direct effect at genotypic level only.

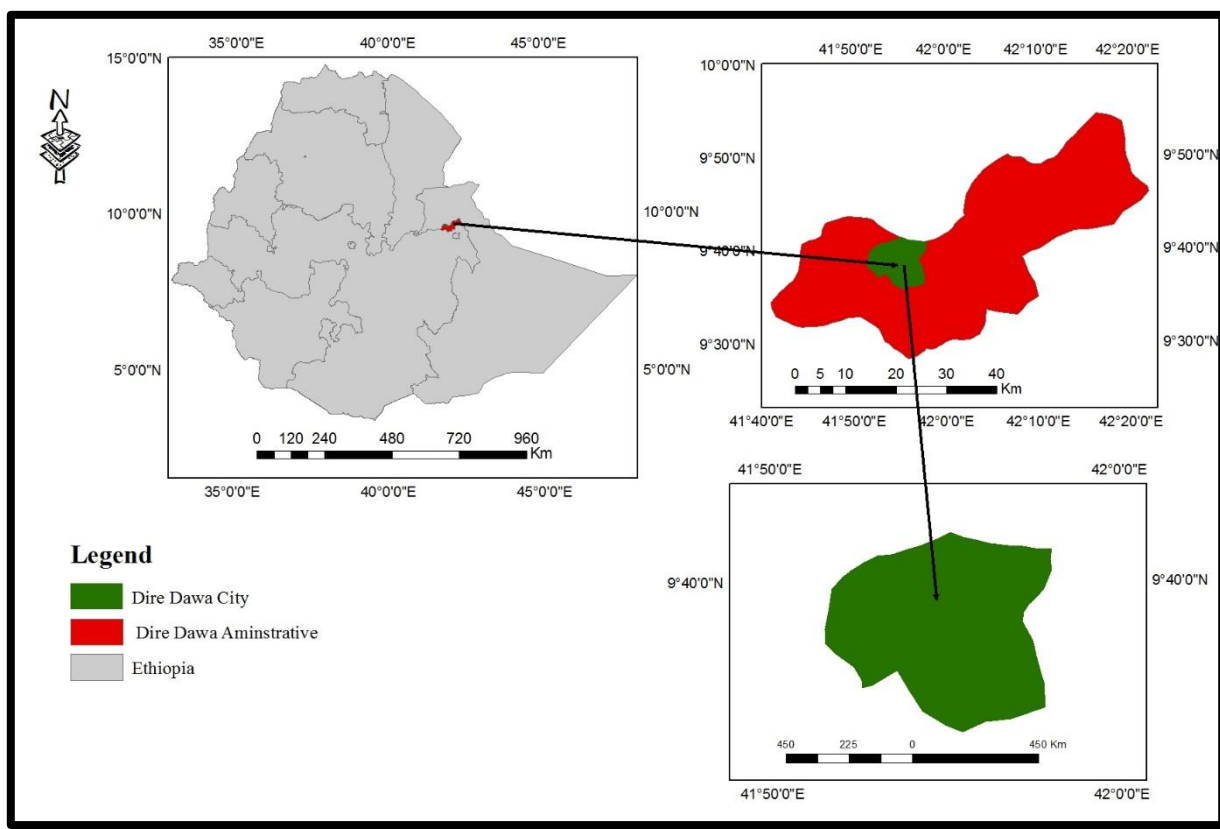
Vijaya *et al.* (2014) found that number of fruits per plant which had higher positive association with dry fruit yield per plant also had the highest direct positive effect. The pericarp weight, plant spread, fruit diameter and oleoresin content were the other characters which had direct positive contribution towards dry fruit yield. Number of seeds per fruit and plant height had highest negative direct effect. Similarly, it had indirect positive influence with fruit length through number of fruits per plant and number of seeds per fruit.

3. MATERIALS AND METHODS

3.1. Description of the Study Area

A field experiment was conducted at Haramaya University's research station located in Dire Dawa, Ethiopia, which is known as Tony Farm. The experiment was conducted from November 2016 to May 2017. The research station is located at a distance of 58km from Haramaya University at $9^{\circ}6'N$ latitude and $41^{\circ}8' E$ longitude, and at an altitude of 1197 meters above sea level. The area receives 520mm mean annual rainfall. It experiences 14.5–21.6 and 28.1–34.6 $^{\circ}C$ mean minimum and maximum temperature ranges, respectively (Metasebia *et al.*, 2008). The soil property of the experimental site is a sandy loam (Tamado *et al.*, 2000) having an average pH of 8.12 and organic matter, total nitrogen and an available phosphorus content of 1.5%, 0.15% and 15.6 mg/kg, respectively, in the 0–30cm soil depth (Adey, 2006).

Figure 1. Location of the Study Area



3.2. Experimental Materials

For this study, four chili varieties and twenty-Six chili accessions, which were collected from Melkasa Agricultural Research Center and Institute of biodiversity conservation, were evaluated during the off-season period from November 2016 to May 2017 at Tony Farm, Diredawa.

Table 3. Passport data of accessions used for the evaluation trials in 2016/2017

Accession No.	Region	Zone	Woreda	Latitude	Longitude	Altitude m.a.s.l.
9098	Amhara	W/Gojjam	Achefer	11-22-43-N	36-56-16-E	2008
229697	Benishangul	Metekel	Dibate	-	-	1440
229699	Amhara	E/Gojjam	Bibugn	11-07-00-N	37-44-00-E	1850
229695	Benishangul	Metekel	Dibate	-	-	1650
28334	-	-	-	-	-	-
229692	Amhara	Agew	Banja	-	-	-
9093	Amhara	W/Gojjam	Achefer	11-31-25-N	36-56-43-E	1956
9086	Amhara	W/Gojjam	Meacha	11-22-27-N	37-07-07-E	1978
9085	Amhara	W/Gojjam	Meacha	11-29-07-N	37-06-01-E	1899
229700	Amhara	E/Gojjam	Bibugn	11-06-00-N	37-44-00-E	1830
9101	Amhara	W/Gojjam	Achefer	11-29-03-N	36-56-43-E	2010
9099	Amhara	W/Gojjam	Achefer	11-30-35-N	36-56-02-E	1964
9094	Amhara	W/Gojjam	Achefer	11-32-18-N	36-58-38-E	1954
9107	Amhara	E/Gojjam	Guzamin	10-16-56-N	37-47-18-	2364
9097	Amhara	W/Gojjam	Achefer	11-34-34-N	37-01-42-	1872
9102	Amhara	W/Gojjam	Achefer	11-29-46-	36-53-46-	2010
230800	Oromia	East	Bedeno	9-8- -N	41- -41-00-	1700
8995	-	-	-	-	-	-
9103	Amhara	W/Gojjam	Achefer	11-29-33-	36-52-3.E	2050
238486	-	-	-	-	-	-
9082	Amhara	West	Meacha	11-25-22-	37-04-54-	1955
9083	Amhara	West	Meacha	11-25-29-	37-05-00-	1961
28337	-	-	-	-	-	-
230799	Oromia	East	Girawa	09-08-00-	41-41-00-	1750
9104	Amhara	W/Gojjam	Bure	10-38-21-	37-05-10-	1974
20208	Oromia	East	Wama	08-50-12-	36-50-52-	1613

Table 4. Varieties used for the evaluation trials in 2016/2017

Variety	Seed Source
V-Unknown-2	MARC
V. Acc No 223654	MARC
V.AVPP.0411	MARC
V-Acc No 223631	MARC

3.3. Treatment and Experimental Design

Trial was laid out as a randomized complete block design (RCBD) with three replications at Tony farm research site. Each plot size was 1.5 m x 2.8 m (with a total plot size of 4.20 m²) and the distance between plots was 1m. Each plot within a replication consists four rows and each row contains five plants with a total of 20 plants per plot. Transplanting to the actual field was done when the seedlings attained 20 to 25 cm height and or at 40 days after sowing. The Seedlings were spaced 30 cm between plants and 70 cm between rows. The experimental plots were fertilized with 200 kg/ha DAP as a side dressing during the transplanting operation in addition, 100 kg/ha UREA, half of it during the transplanting and half of it 15 days after transplanting was applied (EARO, 2004).

As to other agronomic practices, irrigation water was applied to the transplants on surface to facilitate plant establishments, and then upto the time of full plant establishments, water was applied using Furrow irrigation. Based on the environmental conditions, watering was done twice a week afterwards. Hand weeding was done frequently as per the emergence of the weeds. Plant protection was part of the field practices where cultural and chemical control measures were taken and brought about successful results.

3.4. Data Collection

Ten plants per each plot that means the two middle rows were taken for data collection.

1. Days to 50% flowering (DF): Number of days from transplanting to when 50% of plants in a plot open the flower.

- 2. Days to maturity (DM):-** Number of days from transplanting to when the plants in a plot change the color of their fruit from green to red and ready for harvest.
- 3. Plant height (PH):** Length in centimeter of the central axis of the stem, measured from the soil surface up to the tip of the stem and the average was recorded.
- 4. Internode Length (IL):** Length of each Internode on the main stem was measured in centimeters and added together, then divided by the number of internodes on the sample plant to get the average length of internodes for each plot.
- 5. Number of fruits per plant (NFP):** Average number of chili fruits, counted at harvest on 10 sample plants of each plot.
- 6. Fruit length (FL):** Average length of five chili fruits was measured in centimeter on 10 plants of each plot.
- 7. Fruit girth (FG):** Average fruit girth of five chili fruits was measured in centimeter on 10 plants of each plot. This was determined by wounding a thread round the fruit circumference at the widest point and then placing it on a ruler to take the readings.
- 8. Pedicel length (PL):** Average pedicel length of five chili fruits was measured in centimeter on ten plants of each plot. This was done by placing the ruler at the point of pedicel attachment to the fruit and reading at the tip of the pedicel.
- 9. Dry Fruit yield per plot (DFY):** Weights of total dry fruits harvested from each successive harvesting (three round) were recorded and summed up to estimate yield per plot in kilogram.
- 10. Stem width (SW):** Average stem width of ten plants was measured in centimeter at the widest point of the stem for each plot.
- 11. Number of primary branches per plant (PB):** Number of primary branches from ten plants were taken and averaged over the total number of plants from which data was taken.
- 12. Days to first fruit set (FS):** Number of days from transplanting to when the first fruit was set.

3.5. Statistical Data Analysis

3.5.1. Analysis of variance

The mean value of each character under study were summarized and subjected to analysis of variance following the procedure described by Gomez and Gomez (1984) and using SAS Software version 9.1.

Table 5. Analysis of Variance (ANOVA)

Source of variation	Degree of freedom (df)	Mean sum of square (ms)	Expected values of (ms)
Replication	r-1	Msr	$\sigma^2e + r \sigma^2g$
Genotype	g-1	Msg	$\sigma^2e + \sigma^2g$
Error	(r-1) (g-1)	Mse	σ^2e
Total	(rg-1)	Msr+Msg+Mse	

Where, r = Number of replications, g = Number of genotypes, Msr = Mean sum of squares due to replication, Msg = Mean sum of squares due to genotypes, Mse = Mean sum of squares due to error, σ^2e = Error variance, σ^2g = Genotypic variance

3.5.2. Estimation of genetic parameters

The amount of genotypic and phenotypic variability that exist in a species is essential in developing better varieties and in initiating a breeding program. Genotypic and phenotypic coefficients of variation are used to measure the variability that exists in a given population (Burton and Devane, 1953).

Genotypic and phenotypic variances were computed based on the expected mean sum of squares from the ANOVA table as follows.

$$\text{Genotypic variance } (\sigma^2g) = \frac{\text{Msg} - \text{Mse}}{r}$$

$$\text{Phenotypic variance } (\sigma^2p) = \sigma^2g + \sigma^2e$$

$$\text{Environmental variance } (\sigma^2e) = \text{Error mean square}$$

Where, Msg = Mean sum of squares due to genotypes

Mse = Mean sum of squares due to error

r = Number of replications

Phenotypic and genotypic coefficients of variations were worked out as suggested by Burton (1953).

Phenotypic coefficient of variance (PCV)

$$\text{PCV (\%)} = \frac{\sqrt{(\text{phenotypic variance of genotypes})}}{\text{General mean of character}} \times 100$$

Genotypic coefficient of variance (GCV)

$$\text{GCV (\%)} = \frac{\sqrt{(\text{Genotypic variance of genotypes})}}{\text{General mean of characters}} \times 100$$

The genetic components, GCV and PCV were categorized as suggested by Johnson *et al.* (1955): 0–10% – low, 10–20% – moderate, high >20%.

The broad sense heritability (h^2_{bs}) was estimated by following the procedure suggested by Weber and Moorthy (1952) as indicated here below.

$$\text{Heritability} = \frac{V_g}{V_p} \times 100$$

Where, V_p is the phenotypic variance and V_g is the genotypic variance of respective accessions.

Heritability percentages were categorized as demonstrated by Robinson *et al.* (1994): 0–30% – low, 30–60% – moderate, high > 60%.

The expected genetic advance resulting from selection of 5% superior individuals was calculated as per the formula described by Johnson *et al.* (1955).

$$\text{GA} = H \times \sigma_p \times k$$

Where, H is heritability in broad sense, σ_p is phenotypic standard deviation, and k is 2.06 (selection differential at 5% selection index).

Genetic advance as percent mean (GAM) was calculated to compare the extent of predicted advances of different traits under selection by the formula,

$$\text{GAM (\%)} = \frac{\text{Genetic advance}}{\text{General mean of the character}} \times 100$$

Genetic advance values were categorized as low (0–10%), Moderate (10–20%), and high (>20%) broad sense heritability.

3.5.3. Association of characters

The correlation coefficients among all possible character combinations at phenotypic (r_p) and genotypic (r_g) level were estimated employing formula Al-Jibouri *et al.* (1958).

$$\text{Phenotypic correlation} = r_p(xy) = \frac{\text{Cov}_p(xy)}{\sqrt{V_p(x)} \times \sqrt{V_p(Y)}}$$

$$\text{Genotypic correlation} = r_g(xy) = \frac{\text{Cov}_g(xy)}{\sqrt{V_g(x)} \times \sqrt{V_g(Y)}}$$

Where,

$\text{Cov}_p(xy)$ and $\text{Cov}_g(xy)$ are phenotypic and genotypic covariance between x and y characters, while $V_p(X)$ and $V_g(X)$ represent variances of X character and $V_p(Y)$ and $V_g(Y)$ denote variances of Y character at phenotypic and genotypic level, respectively.

The coefficient of correlation will be tested for their statistical significance by using t test as,

$$t = \frac{r\sqrt{(n-1)}}{\sqrt{(1-r^2)}}$$

Where n = number of treatment. The calculated value of t was compared with 't' table value at n-2 degree of freedom at 1 and 5 percent level of significance.

Path Coefficient Analysis

Path coefficient analysis was estimated with the formula given by Dewey and Lu (1959).

$$r_{ij} = p_{ij} + \sum r_{ik}p_{jk}$$

Where:

r_{ij} = the association between independent variables (i) and dependent variables (j) as measured by phenotypic and genotypic correlation coefficient.

P_{ij} = component of direct effect of independent variable (i) on the dependent variable (j) as measured by the phenotypic and genotypic path coefficient.

$\sum r_{ik}P_{jk}$ = is the summation of components of indirect effect of a given independent variable (i) on a given dependent variable (j) via all other independent characters.

The residual effect, which determines how best the causal factors account for the variability of the dependent factor, was calculated as described by Dewey and Lu *et al.* (1959):

$$1 = P^2_r + \sum P_{ij} \cdot r_{ij}$$

Where, P^2_r is the residual factor, P_{ij} is the direct effect of yield by i^{th} trait on j^{th} trait, and r_{ij} is the correlation of dependent variable with the i^{th} trait.

Small P^2_r value (P^2_r , nearly zero) indicates that the dependent trait considered (yield) is fully explained by the variability in the independent traits.

Higher P^2_r value indicates that some other factors which have not been considered need to be included in the analysis to account fully for the variation in the dependent trait.

4. RESULTS AND DISCUSSION

The results on genetic variability, associations of characters and path coefficient analysis of *Capsicum annuum* are presented and discussed here under.

4.1. Mean, Range and Analysis of Variance for 12 Traits of Chili Accessions and Varieties

4.1.1. Mean and range

Mean and range values for the 12 agronomic traits were presented in table 6. Days to fifty percent flowering were shortest for accession '9099' and longest for '9101' with a mean of 38.1. The mean dry fruit yield per plot recorded in the present study was 0.618 kg/plot. The least and highest dry fruit yield per plot were obtained from accession 229697 (0.279kg/plot) and 9098 (0.966kg/plot), respectively. The highest fruit number per plant was obtained for variety 'V.AVPP.0411' and the least for accession '9099' with a mean value of 48.26. Fruit length varied from 4cm in V-Unknown-2, 9086, 9099, and 9082' to 11 cm in V.AVPP.0411.

The widest fruit girth was obtained for accession '9107' and the narrowest for '230799'. The internode length was high for 'V-Acc No 223631' and short for 'V. Acc No-223654'. Stem width was smallest for '229697, 9099' and largest for '9098, V-AVPP.0411'. Days to maturity were shortest for '9104' and longest for 'V.AVPP.0411'.

The highest plant height at maturity was recorded for the V.AVPP.0411 and the least plant height was obtained from 229697. The mean plant height recorded in the study was 49.9 cm. The present study indicated that the least number of primary branches per plant at maturity were obtained for 9099 and the highest for V.AVPP.0411. The population mean for this trait was 7.53. The average number of days to first fruiting was 61; while accession 9107 was early fruiting and accession 9086 take longest days to first fruiting. In general, the overall performance of the genotypes showed that about 43.3% of the genotypes yielded higher than the population mean (0.618kg/plot).

Similar finding to the present study were reported by Shimeles *et al.* (2016), Joseph (2012), Vijaya *et al.* (2014) and Tadesse (2013) who reported a wide range of means for fruit number,

plant height, yield per plant, number of primary branch per plant, days to fifty percent flowering, dry fruit yield per plant, fruit length, fruit width and pedicel length. In general, range and mean values in this study suggested the existence of sufficient variability among the tested accessions for the majority of the traits studied and their considerable potentials in the improvement of pepper.

Table 6. Minimum, maximum, mean values and SE of mean for the 12 quantitative traits of the chili accessions and varieties

Traits	Minimum		Maximum		Mean	SE
	Score	Accession	Score	Accession		
DF	33	9099	45	9101	38.1	2.3
FS	50	9107	68	9086	61	2.47
PB	3	9099	14.5	V.AVPP.0411	7.53	0.849
SW	3.5	229697, 9099	9.3	9098, V.AVPP.0411	6.64	0.73
FG	3.6	230799	6.8	9107	5.39	0.685
DM	120.6	9104	156	V.AVPP.0411	136.4	6.78
FL	4	V-Unknown-2, 9086, 9099, 9082	11	V.AVPP.0411	7.17	0.65
PL	2.5	9098, 229697, 9097, 9094 9102, 238486, 9083	3.83	9104	2.92	0.31
PH	41	229697	62.16	V.AVPP.0411	49.9	6.26
NFP	33.3	9099	70	V.AVPP.0411	48.26	4.62
IL	2.7	V.AccNo.223654	8.1	V.Acc No.223631	5.17	0.74
DFY	0.279	229697	0.966	9098	0.618	0.09

Where, DF: Days to fifty percent flowering, FS: Days to first fruit set, PB: Primary branch per plant, SW: Stem width, FG: Fruit girth, DM: Days to maturity, FL: Fruit length, PL: Pedicel length, PH: Plant height, NFP: number of fruit per plant, IL: Internode length, DFY: Dry fruit yield per plot

4.1.2. Analysis of variance (ANOVA)

Analysis of variance (ANOVA) was carried out for dry fruit yield per plot and other yield related traits as outlined by (Gomez and Gomez, 1984). The results are presented in Table 7. Analysis of variance revealed highly significant ($P \leq 0.01$) mean squares for all traits except for days to fifty percent flowering which is significant at ($p < 0.05$) and Fruit girth, pedicel length and plant height which is non-significant. Highest coefficients of variation were observed for dryfruit yield per plot (25.5) and the least one is for days to first fruit setting (7). The highly significant differences indicate the existence of large variability among the accessions.

Table 7. Mean squares from analysis of variance for the 12 quantitative characters of chili accessions and varieties.

Source of variation	Df	DF	FS	PB	SW	FG	DM	FL	PL	PH	NFP	IL	DFY
Rep	2	18.30	17.68	1.44	0.678	0.278	2.5	0.478	0.0058	128.1	27.9	1.05	0.0116
Accession	29	38.44*	49.83**	40.75**	12.25**	1.58	495.6**	18.58**	0.4065	171.5	513**	5.25**	0.190**
Error	58	16.44	18.33	2.16	1.59	1.41	138	1.27	0.2927	117.7	64	1.66	0.0248
CV (%)	–	10.5	7.0	19.5	19	22.0	8.6	15.7	18.5	21.8	16.6	24.9	25.5

Where, ** and * indicate significant differences at 1% and 5%, respectively. df: degree of freedom DF: Days to fifty percent flowering, FS: Days to first fruit set, PB: Primary branch per plant, SW: Stem width, FG: Fruit girth, DM: Days to maturity, FL: Fruit length, PL: Pedicel length, PH: Plant height, NFP: number of fruit per plant, IL: Internode length, DFY: Dry fruit yield per plot and CV (%): coefficient of variance.

4.2. Estimates of Genetic Parameter for 12 Traits of Chili

The extent of variability in respect of environmental variance (σ^2_e), phenotypic and genotypic variance, heritability (H%), genetic advance (GA), genetic advance as percent mean (GAM), phenotypic and genotypic coefficients of variation were summarized in Table 8.

4.2.1. Estimates of genotypic and phenotypic coefficient variation

Estimated variance components, phenotypic coefficient of variation (PCV) and genotypic Coefficient of variation (GCV) of the traits studied are presented in Table 8. A greater phenotypic coefficient of variation (PCV) was observed than genotypic coefficient of variation (GCV) for all the traits. Similar results on chili were reported by Seleshi *et al.* (2016), Verma *et al.* (2004), and Vijaya *et al.* (2014). This indicated that the apparent variation is not only due to genotypes but also due to the influence of environment.

PCV and GCV values were categorized as low, moderate and high values as indicated by Sivasubramaniah and Menon (1973) as follows Low = 0-10%, Moderate = 10-20%, High > 20. The high phenotypic coefficient of variation was observed for primary branch per plant followed by fruit dry weight per plot, fruit length, stem width, number of fruit per plant, plant height and fruit girth. On the other hand, relatively moderate values were observed for pedicel length followed by days to fifty percent flowering and days to maturity. Low phenotypic coefficient of variation was noted on days to first fruit set.

The genotypic coefficient of variation was high for primary branch per plant followed by fruit dry weight per plot, fruit length, stem width, number of fruit per plant and internode length. On the other hand, relatively lower genotypic coefficient of variation was observed for plant height followed by days to maturity, days to fifty percent flowering, pedicel length, days to first fruit set and stem width.

High phenotypic and genotypic coefficients of variations were obtained for primary branch per plant, stem width, fruit length, number of fruit per plant, internode length and fruit dry weight per plot. The high GCV and PCV value of the above traits suggest that the possibility of improving those traits through selection. Similar findings on chili were reported by Seleshi *et al.* (2016) for number of branches and internode length, (Sreelathakumary and Rajamony, 2003) for yield per plant, fruit weight, fruits per plant and fruit length, (Manju

and Sreelathakumary, 2002), and Sonia *et al.* (2006) for number of fruits per plant, (Dipendra and Gautam, 2002) for dry fruit yield per plant.

The difference between PCV and the corresponding GCV values was relatively higher for Fruit girth, plant height, pedicel length and internode length, indicating the higher influence of the environment on the traits. However, this difference was moderate for fruit dry weight per plot, stem width and days to fifty percent flowering and comparatively low for number of fruit per plant, primary branch per plant, days to maturity, days to first fruit setting and fruit length. The small difference indicating that there is a minimal influence of environment on the expression of these traits. In addition, it indicates the presence of sufficient genetic variability for observed traits may facilitate the selection process (Demewez *et al.*, 2014). Therefore, selection based on phenotypic performance of the traits would be effective to bring considerable improvement in these traits.

4.2.2. Estimates of heritability

Heritability is the portion of phenotypic variation which is transmitted from parent to progeny. Higher the heritable variation, greater will be the possibility of fixing the characters by selection. Hence, heritability studies are of foremost importance to judge whether the observed variation for a particular character is due to genotype or due to environment (Janaki *et al.*, 2015). Burton and De Vane (1953) suggested that genetic coefficients of variability, along with heritability estimates, would provide a reliable indication of expected degree of improvement through selection. Broad sense heritability (h^2), an estimate of the total contribution of the genotypic variance to the total phenotypic variance ranged from 3.86 for fruit girth to 85.62 for primary branch per plant (Table 8). The heritability percentage categorized as low, moderate and high as followed by Robinson *et al.* (1949), as follows. Low=0-30%, Moderate=30-60%, High \geq 60%.

Accordingly, high heritability estimates were obtained for primary branch per plant followed by fruit length, number of fruit per plant and stem width. Similar findings on chili were reported by (Manju and Sreelathakumary, 2002), (Khurana *et al.*, 2003), (Seleshi *et al.*, 2016) for number of branches, (Sing *et al.*, 2009) and (Sreelathakumary and Rajamony, 2004) for number of fruits per plant and fruit length, Sing *et al.* (2009) for primary branch per plant. High heritability for different traits indicated that large proportion of phenotypic

variance has been attributed to genotypic variance and therefore, reliable selection could be made for these traits on the basis of phenotypic expression (Maurya *et al.*, 2015).

On the other hand, relatively moderate estimates of heritability was found for days to maturity followed by internode length, days to first fruit set and days to fifty percent flowering. Such results on chili were reported by (Seleshi *et al.*, 2016) for internode length, (verma *et al.*, 2004) for days to fifty percent flowering. In addition, low broad sense heritability estimates were obtained for the fruit girth, pedicel length, and plant height. Thus, these indicated that a larger proportion of phenotypic variance was attributed to genotypic variance and thus a reliable selection could be made for most of the traits based on phenotypic expression. Unlike the current study, Manju and Sreelathakumary (2002) reported low heritability for primary branch per plant.

4.2.3. Estimates of genetic advance

Genetic advance is the measure of genetic gain under selection and expression in percentage of means (Rathod *et al.*, 2016). Hence, genetic advance is a useful indicator of progress that can be expected as a result of exercising selection on a population (Sood *et al.*, 2009). The genetic advances as percent of mean (GAM) at 5% selection intensity is presented in Table 8. It ranged from 1.79 for fruit girth to 90.65 for primary branch per plant.

The GA as percent of mean was categorized as low, moderate and high as described by Johnson *et al.* (1955) as follows. Low= 0-10 %, Moderate= 10-20% and High ≥ 20 . Maximum genetic advance as percent of mean (GAM) at 5% selection intensity was recorded for primary branch per plant followed by fruit dry weight per plot, fruit length, stem width, number of fruit per plant and internode length. Similar findings to the present study on chili were reported by Singh *et al.* (2005) for dry yield per plant, Seleshi *et al.* (2016) for internode length, (Manju and Sreelathakumary, 2002) for fruits per plant and fruit length, Vijaya *et al.* (2014) for number of fruits per plant, fruit length, dry fruit yield per plant, number of branches per plant.

Low genetic advances were observed for characters like fruit girth, pedicel length, plant height, days to fifty percent flowering and days to first fruit set. Sarker (2013) found similar results on chili for days to fifty percent flowering. This is due to low PCV and GCV value of variability. This shows the importance of genetic variability for improvement through selection Vijaya *et al.* (2014).

The effectiveness of selection depends upon genetic advance of the character selected along with heritability (Manju and Sreelathakumary, 2002). In the present study, high genetic advance coupled with high heritability was obtained for primary branch per plant, fruit length, number of fruit per plant, stem width and dry fruit weight per plot. Similar findings were obtained by Sarker (2013) for number of fruit per plant and fruit length, (Janaki *et al.*, 2015) for number of primary branches per plant, Number of fruits per plant, Fruit length, (Vijaya *et al.*, 2014) for number of primary branches, number of fruit per plant, fruit length and dry fruit yield per plant. These offer opportunities for selection, and Indicating the predominance of additive gene action and hence direct phenotypic selection is useful with respect to these traits (Janakil *et al.*, 2015).

Table 8. Estimates of Phenotypic (σ^2_p) and Genotypic variance (σ^2_g), Phenotypic coefficient of variation (PCV) and Genotypic Coefficient of variation (GCV), Broad sense heritability (H%), Expected genetic advances (GA) and Genetic advance as percent of mean (GAM)

Traits	(σ^2_p)	(σ^2_g)	(σ^2_e)	PCV%	GCV%	H%	GA	GAM%
DF	23.77	7.33	16.44	12.6	6.98	30.85	3.09	8.00
FS	28.83	10.50	18.33	8.8	5.30	36.42	4.03	6.60
PB	15.02	12.86	2.16	51.5	47.7	85.62	6.83	90.65
SW	5.14	3.55	1.59	34.2	28.3	69.09	3.23	48.65
FG	1.47	0.06	1.41	22.45	4.40	3.86	0.10	1.79
DM	257.2	119.2	138	11.76	7.99	46.35	15.3	11.23
	7.04	5.77	1.27	36.9	33.5	81.96	4.47	62.4
FL								
PL	0.33	0.04	0.29	19.6	6.70	11.47	0.14	4.65
PH	135.63	17.93	117.7	23.3	8.50	13.22	3.17	6.36
NFP	213.67	149.67	64	30.3	25.4	70.05	21.10	43.7
IL	2.86	1.20	1.66	32.7	21	41.89	1.46	28.2
DFY	0.08	0.06	0.02	45.8	37.2	68.95	0.40	65

Where, DF: Days to fifty percent flowering, FS: Days to first fruit set, PB: Primary branch per plant, SW: Stem width, FG: Fruit girth, DM: Days to maturity, FL: Fruit length, PL: Pedicel length, PH: Plant height, NFP: number of fruit per plant, IL: Internode length, DFY: Dry fruit yield per plot.

4.3. Association of Characters for 12 Traits of Chili

Yield of a crop is the result of interaction of a number of interrelated characters. Therefore, selection should be done based on these component characters after assessing their correlation with the yield (Vijaya *et al.* 2014). In the present study, associations of traits for all the 12 quantitative characters were determined for the experimental materials that included 26 accessions and 4 varieties and traits were investigated for their relationship with yield as well as among themselves using genotypic and phenotypic correlation analysis (Table 9 and 10).

4.3.1. Correlation analysis

4.3.1.1. Genotypic correlation

With genotypic correlations taken as reference, it is found that dry fruit yield per plot is highly significantly and positively correlated with days to fifty percent flowering, primary branch per plant, stem width, days to maturity, fruit length, plant height, and number of fruit per plant. The positive and highly significant correlation indicates a strong association of these traits with dry fruit yield (Demewez *et al.*, 2014). Similar findings on chili were reported by (Abraham *et al.*, 2017; Luetel *et al.*, 2013, Yattung *et al.*, 2014) for fruit number per plant, (Singh *et al.*, 2014; Sharma *et al.*, 2009) for fruit length, (Sharma and Sridevi, 2016) for plant height and fruit length, (Yattung *et al.*, 2014, Sharma and Sridevi, 2016) number of fruit per plant, (Abraham *et al.*, 2017; Yattung *et al.*, 2014) for primary branch per plant. These characters can therefore, be used to the advantage of the breeder for selecting productive genotypes. In contrast, to present study Ajjapplavara (2005) reported negative correlation between fruit yield and primary branch per plant. Similarly, dry fruit yield per plot is correlated significantly and positively with fruit girth but non-significant positive with internode length. Kumari *et al.* (2011) reported similar results for fruit girth. Hence, dry fruit yield per plot can be improved by selecting those traits. Nonetheless, fruit dry weight per plot had non-significant negative correlation with days to first fruiting.

Days to fifty percent flowering, fruit girth, days to maturity, and fruit length showed positive significant association for internode length, whereas non-significant positive association was recorded for primary branch per plant, stem width, pedicel length, plant height, and number of fruit per plant. Similar results were reported by (Sharma *et al.*, 2009) for pedicel length, (Singh *et al.*, 2009) for primary branch per plant, (Shimeles *et al.*, 2016) for

days to fifty percent flowering. On the other hand, non-significant negative association was recorded with days to first fruit set.

Highly significant positive correlation of days to fifty percent flowering, primary branch per plant, stem width, days to maturity, fruit length, and plant height with number of fruit/plant revealed that improvement in these traits would enhance number of fruit/plant and ultimately yield. While non-significant positive association was recorded for fruit girth and pedicel length. Such results have been reported by Singh *et al.* (2014), Yattung *et al.* (2014), and Shimeles *et al.* (2016) for primary branch per plant, Sharma *et al.* (2009) for pedicel length. On the other hand, significant negative association was recorded with days to first fruit set.

Highly significant Positive correlation was recorded for plant height with days to fifty percent flowering, primary branch per plant, stem width, days to maturity, and fruit length. Similar results were reported by Singh *et al.* (2009) for primary branch per plant, Shimeles *et al.* (2016) for days to fifty percent flowering and fruit length. Moreover, fruit girth had significant positive association with plant height. On the other hand, negative significant association was recorded with days to first fruit set.

The correlation studies revealed that days to fifty percent flowering, primary branch per plant, stem width, and days to maturity gave highly significant positive association with fruit length. This is in tune with the finding of Shimeles *et al.* (2016) for days to fifty percent flowering. Fruit girth possesses significant positive correlation with fruit length. Nonetheless, fruit length had significant negative correlation with days to first fruit set.

Days to maturity had highly significant positive correlation with days to fifty percent flowering, primary branch per plant, and stem width. However, it had significant negative correlation with days to first fruit set. Fruit girth is correlated significantly and positively with stem width. In contrast, days to first fruit set had significant negative correlation with fruit girth.

The trait, stem width had highly significant positive association with days to first fruiting and primary branch per plant. Nonetheless, it is correlated significantly negatively with days to first fruit set. The association between primary branches per plant with days to fifty percent flowering was significant and negative.

To this end the genotypic correlation profiles indicate that days to fifty percent flowering, primary branch per plant, stem width, days to maturity, fruit length, plant height, number of fruit per plant are important yield components. So, it is suggested that dry fruit yield in chili could be increased by giving weightage to those traits and consequent selection would be rewarding.

Table 9. Genotypic correlation coefficient (rg) of yield and yield related 12 quantitative traits of 26 chili accessions and 4 varieties.

Variables	DF	FS	PB	SW	FG	DM	FL	PL	PH	NFP	IL	DFY
DF	1											
FS	-0.404*	1										
PB	0.982**	0.442*	1									
SW	0.960**	-0.474	0.943**	1								
FG	0.329	-0.467*	0.321	0.373*	1							
DM	0.929**	-0.431*	0.923**	0.906**	0.303	1						
FL	0.972**	-0.517*	0.967**	0.986**	0.382*	0.923**	1					
PL	0.193	-0.226	0.133	0.172	0.257	0.024	0.138	1				
PH	0.973**	-0.437*	0.986**	0.931**	0.363*	0.929**	0.955**	0.149	1			
NFP	0.970**	-0.490*	0.979**	0.943**	0.349	0.929**	0.966**	0.137	0.987**	1		
IL	0.426*	-0.110	0.349	0.357	0.425*	0.399*	0.371*	0.180	0.330	0.315	1	
DFY	0.965**	-0.496*	0.950**	0.994**	0.373*	0.914**	0.992**	0.148	0.944**	0.961**	0.353	1

* and ** where significant and highly significant at 5% and 1%. DF: Days to fifty percent flowering, FS: Days to first fruit set, PB: Primary branch per plant, SW: Stem width, FG: Fruit girth, DM: Days to maturity, FL: Fruit length, PL: Pedicel length, PH: Plant height, NFP: number of fruit per plant, IL: Internode length, DFY: Dry fruit yield per plot.

4.3.1.2. Phenotypic correlation

Phenotypic coefficients of correlation are presented in Table 10. In the present investigation, dry fruit yield per plot had highly significant ($p \leq 0.01$) positive correlation with all the traits studied except days to first fruit set and pedicel length. These findings are in consonance with the finding of Sood *et al.* (2009) and Yattung *et al.* (2014) for number of fruit per plant, Singh *et al.* (2014), and Sharma *et al.* (2009) for fruit length, Abraham *et al.* (2017), and Yattung *et al.* (2014) for number of primary branch per plant. This indicates that improvement in these traits would enhance dry fruit yield per plot. Moreover, it is correlated significantly and positively with pedicel length.

Internode length was positive and highly significantly correlated with days to fifty percent flowering, primary branch per plant, stem width, fruit girth, days to maturity, fruit length, pedicel length, plant height, and number of fruit per plant. Number of fruit per plant had highly significant positive relationship with days to fifty percent flowering, primary branch per plant, stem width, fruit girth, fruit length, days to maturity, plant height. Moreover, pedicel length had significant positive correlation with number of fruit per plant. Similar results were reported by Bijalwan and Mishra (2013) for primary branch per plant, (Sing *et al.*, 2014) for plant height.

The correlation between Plant height and days to fifty percent flowering, primary branch per plant, stem width, fruit girth, days to maturity, fruit length, and pedicel length were observed to be positive and highly significant. These results were in accordance with the findings of (Sing *et al.*, 2014) for primary branch per plant. Pedicel length showed highly significant positive association with days to fifty percent flowering and fruit girth. Besides, it showed significant positive association with primary branch per plant, stem width, days to maturity, and fruit length.

Phenotypic correlation coefficient between fruit length and days to fifty percent flowering, primary branch per plant, stem width, fruit girth, and days to maturity were positive and highly significant. Nonetheless, fruit length exhibit significant negative correlation with days to first fruiting. Days to maturity had highly significant positive association with most of the yield components like days to fifty percent flowering, primary branch per plant, stem width, and fruit girth.

Primary branch per plant, stem width had highly significant positive correlation with fruit girth. Moreover, fruit girth correlated significantly positive with primary branch. Days to fifty percent flowering and primary branch per plant were found to have highly significant positive association with stem width. However, stem width correlated non-significant negative association with days to first fruiting.

Highly significant positive associations were observed between days to fifty percent flowering and primary branch per plant. However, primary branch per plant were found to have negative non-significant association with days to first fruit setting. Days to fifty percent flowering and days to fruit set had non-significant positive association.

From the above discussion of phenotypic correlation it may be concluded that there was highly significant positive correlation of dry fruit yield per plot with days to fifty percent flowering, primary branch per plant, stem width, fruit width, days to maturity, fruit length, plant height, number of fruit per plant, and internode length. So, these traits may be utilized for future breeding programme.

Table 10. Phenotypic correlation coefficient (rp) of yield and yield related 12 quantitative traits of 26 chili accessions and 4 varieties.

Variables	DF	FS	PB	SW	FG	DM	FL	PL	PH	NFP	IL	DFY
DF	1											
FS	0.018	1										
PB	0.848**	-0.195	1									
SW	0.859**	-0.142	0.913**	1								
FG	0.574**	0.085	0.386*	0.477**	1							
DM	0.872**	-0.034	0.864	0.872**	0.531**	1						
FL	0.827**	-0.235*	0.952**	0.939	0.439**	0.854**	1					
PL	0.463**	0.125	0.265*	0.379*	0.544**	0.373*	0.287**	1				
PH	0.853**	0.096	0.812**	0.815**	0.655**	0.855**	0.800**	0.528**	1			
NFP	0.864**	-0.153	0.955**	0.921**	0.479**	0.895**	0.946**	0.357*	0.870**	1		
IL	0.492**	0.154	0.394**	0.427**	0.503**	0.489**	0.424**	0.406**	0.496**	0.405**	1	
DFY	0.857**	-0.160	0.929**	0.966**	0.486**	0.888**	0.966**	0.377*	0.852**	0.956**	0.450**	1

* and ** where significant and highly significant at 5% and 1%. DF: Days to fifty percent flowering, FS: Days to first fruit set, PB: Primary branch per plant, SW: Stem width, FG: Fruit girth, DM: Days to maturity, FL: Fruit length, PL: Pedicel length, PH: Plant height, NFP: number of fruit per plant, IL: Internode length, DFY: Dry fruit yield per plot.

4.3.2. Path coefficient analysis of dry fruit yield Chili with other traits

Knowledge of correlation alone is often misleading as the correlation observed may not be always true. Two characters may show correlation just because they are correlated with a common third one (Khan and Dar, 2009). Under such circumstances, path analysis helps in partitioning of correlation coefficients into direct and indirect effects, permitting a critical examination of the relative importance of each trait (Kumar *et al.*, 2013). Correlations between yield and yield components were partitioned into direct and indirect effects to know the particular factor responsible for that correlation (Table 11 and 12).

4.3.2.1. Phenotypic direct and indirect effect of various characters on dry fruit yield per plot

Phenotypic correlations of the different characters were partitioned to path coefficient (Table 11) with the view to identifying important fruit characters having direct effect on yield. The path coefficient analysis at the phenotypic level based on dry fruit yield per plot as dependent variable showed that stem width (0.4059), days to maturity (0.0401), Fruit length (0.4293), pedicel length (0.0122), plant height (0.1081), number of fruit per plant (0.2610), and internode length (0.0227) revealed positive direct effect on dry fruit yield. Thus selection on the basis of those traits would be a paying proposition for evolving high yielding genotypes. On the other hand, days to fifty percent flowering, days to first fruit setting, primary branch per plot, and fruit girth had negative direct effect on dry fruit yield per plot.

Stem width employed direct positive effect (0.4059) on dry fruit yield per plot as well as indirect positive effects via days to first fruit set, days to maturity, fruit length, pedicel length, plant height, number of fruits per plant, and internode length. In contrast to the result of the present study Abraham *et al.* (2017) found negative direct effect of stem width. This contradiction may attributed to the environmental difference of study area. However, stem width exerted negative indirect effect on dry fruit yield per plot through days to fifty percent flowering, primary branch per plant, and fruit girth. Stem width which showed high positive correlation with dry fruit yield per plot is due to its high direct effect and indirect effect through fruit length and number of fruit per plant.

Number of fruits per plant applied positive direct effect (0.2610) and positive indirect effects by means of stem width, days to first fruit set, fruit length, days to maturity, pedicel length, plant height, and internode length. This finding is in harmony with the findings of

the previous report by (Abraham *et al.*, 2017; Bijalwan and Mishra, 2013; Yatung *et al.*, 2014; Sharma *et al.*, 2009) for direct effect of number of fruit per plant on yield. The highly significant positive association of number of fruit per plant and dry fruit yield per plot were the result of positive indirect effect of these traits via stem width, fruit length and plant height and also some individual direct effect of number of fruits per plant towards dry fruit yield per plot.

Days to fifty percent flowering had negative direct effect (-0.0226) on dry fruit yield per plot. This trait also exhibited negative indirect effect on dry fruit yield per plot through days to first fruit setting, primary branch per plant and fruit girth. On the other hand, days to fifty percent flowering had an indirect positive effect on dry fruit yield per plot, through stem width, days to maturity, fruit length, pedicel length, plant height, fruit per plant, and internode length.

Days to first fruit setting had negative direct (-0.0194) and indirect effects on dry fruit yield per plot through days to fifty percent flowering, stem width, fruit girth, fruit length, number of fruit per plant. On the other hand, days to first fruit set had an indirect and positive effect on dry fruit yield per plot, through primary branch per plant, days to maturity, pedicel length, plant height, drop per plant, and internode length. Days to first fruit set which correlated non-significant negative with dry fruit yield per plot is due to its negative direct effect as well as negative indirect effect through number of fruit per plant, fruit length, days to maturity, fruit girth, and stem width.

Primary branch per plant had negative direct effect on dry fruit yield per plot. This is in tune with an earlier finding of (Yatung *et al.*, 2014). Moreover, it had negative indirect effect via days to fifty percent flowering and fruit girth. In contrast, primary branch per plant expressed positive indirect effect through days to first fruit setting, stem width, days to maturity, fruit length, pedicel length, plant height, number of fruit per plant and internode length. Even though primary branch per plant had negative direct effect its correlation with dry fruit yield per plot is highly significant positive. This is due to high positive indirect effect through stem width, number of fruit per plant, and fruit length.

Phenotypic path coefficient analysis results revealed that fruit girth had negative direct effect and indirect effect via primary branch per plant, days to first fruit setting and days to fifty percent flowering. Supporting evidence of direct negative influence of fruit girth on

yield had been reported earlier by (Sharma *et al.*, 2009). On the other hand fruit girth exerted positive indirect effect via stem width, days to maturity, fruit length, pedicel length, plant height, number of fruit per plant and internode length. Result obtained from phenotypic correlation indicated that fruit girth had positive highly significant association with dry fruit yield per plot but path coefficient analysis showed that it had negative direct effect on yield. This contradiction is because of positive indirect effect of stem width, fruit length, and number of fruit per plant.

Days to maturity possess positive direct effect on dry fruit yield per plot. Similarly it had positive indirect effect via days to first fruit set, stem width, days to maturity, fruit length, pedicel length, plant height, number of fruit per plant and internode length. On the other hand, it exerted negative indirect effect through fruit girth, primary branch per plant and days to fifty percent flowering. Days to maturity associated highly significantly positive with dry fruit yield per plot. This association is the result of positive direct effect and high indirect effect through stem width, fruit length, and number of fruit per plant.

Fruit length possesses highest positive direct effect on dry fruit yield per plot. These results were in accordance with the findings of (Abraham *et al.*, 2017; Bijalwan and Mishra, 2013). Furthermore, it had positive indirect effect via internode length, number of fruit per plant, plant height, pedicel length, days to maturity, stem width and days to first fruit setting. But it exerted negative indirect effect through fruit girth, primary branch per plant and days to fifty percent flowering. The highly significant positive association of fruit length and dry fruit yield per plot were the result of positive indirect effect of these traits via days to maturity, stem width, plant height, and number of fruit per plant and also direct effect of fruit length, towards dry fruit yield per plot.

Pedicel length had positive direct effect on dry fruit yield per plot, as also earlier recorded by Bijalwan and Mishra (2013). Stem width, days to maturity, fruit length, plant height, number of fruit per plant and internode length are traits through which pedicel length exerted indirect positive effect on dry fruit yield per plot. However, pedicel length had negative indirect effect on dry fruit yield per plot via fruit girth, days to first fruit set, primary branch per plant and days to fifty percent flowering.

Plant height had positive direct effect on dry fruit yield per plant. Beside it exerted positive indirect effect via stem width, days to maturity, fruit length, pedicel length, number of fruit per plant and internode length. In contrary, it had negative indirect effect through fruit

girth, primary branch per plant, days to first fruit set and days to fifty percent flowering. The result of phenotypic correlation showed that plant height and dry fruit yield per plot had highly significant positive correlation

The number of fruits per plant exhibited direct positive effect and indirect effect through other characters like days to first fruit setting, stem width, days to maturity, fruit length, pedicel length, plant height and internode length. These findings are in consonance with (Sharma *et al.*, 2014) for positive direct effect of Number of fruit per plant. Nonetheless, it had negative indirect effect, via fruit girth, days to fifty percent flowering and primary branch per plant. Number of fruit per plant had highly significant positive correlation with dry fruit yield per plot. Path analysis revealed that this association is due to positive direct effect of number of fruit per plant and positive indirect effect through stem width, fruit length, and plant height.

Internode length exerted positive direct effect on dry fruit yield per plot and exerted positive indirect effect through stem width, days to maturity, fruit length, pedicel length, plant height and number of fruit per plant. On the other hand, internode length exerted negative indirect effect through days to first fruit set, primary branch per plant and days to fifty percent fruiting. The residual (0.158) indicated that the independent variables included in this study explained (84.2%) of the total variation in the dependent variables that is dry fruit yield per plot. The unexplained variation in the phenotypic path coefficient was 0.158. It predicted that 84.2% variation at phenotypic level had been determined and further indicated that some more factors need to be considered in this study contributed to dry fruit yield per plot. Thus, few more traits may be considered while selecting the genotypes for high yield.

Overall, the phenotypic path analysis confined that direct effect of stem width, fruit length, number of fruit per plant, plant height, days to maturity, internode length, and pedicel length and negative direct effect of days to fifty percent flowering, days to first fruit set, number of primary branch per plant, and fruit girth should be considered simultaneously for amenability in dry fruit yield of chili selections.

Table 11. Estimates of phenotypic direct effects (bold and diagonal) and indirect effects (off diagonal) of traits via other independent

Variable	DF	FS	PB	SW	FG	DM	FL	PL	PH	NFP	IL	rp
DF	-0.0226	-0.0002	-0.1711	0.3487	-0.0223	0.0349	0.3551	0.0057	0.0922	0.2255	0.0112	0.857**
FS	-0.0004	-0.0111	0.0394	-0.0579	-0.0033	-0.0013	-0.1007	0.0015	0.0104	-0.0400	0.0035	-0.160
PB	-0.0191	0.0022	-0.2016	0.3706	-0.0150	0.0346	0.4087	0.0032	0.0877	0.2493	0.0090	0.929**
SW	-0.0194	0.0016	-0.1841	0.4059	-0.0185	0.0349	0.4033	0.0046	0.0880	0.2405	0.0097	0.966**
FG	-0.0130	-0.0009	-0.0778	0.1938	-0.0388	0.0213	0.1885	0.0066	0.0707	0.1252	0.0114	0.487**
DM	-0.0197	0.0004	-0.1743	0.3540	-0.0206	0.0401	0.3668	0.0046	0.0924	0.2338	0.0111	0.888**
FL	-0.0187	0.0026	-0.1920	0.3813	-0.0170	0.0342	0.4293	0.0035	0.0865	0.2469	0.0096	0.966**
PL	-0.0104	-0.0014	-0.0536	0.1542	-0.0211	0.0149	0.1233	0.0122	0.0571	0.0934	0.0092	0.377*
PH	-0.0192	-0.0011	-0.1637	0.3307	-0.0254	0.0343	0.3438	0.0064	0.1081	0.2273	0.0113	0.852**
NFP	-0.0195	0.0017	-0.1926	0.3740	-0.0186	0.0359	0.4061	0.0044	0.0941	0.2610	0.0092	0.955**
IL	-0.0111	-0.0017	-0.0795	0.1733	-0.0195	0.0196	0.1823	0.0050	0.0537	0.1057	0.0227	0.450**

R= 0.158

* and ** where significant and highly significant at 5% and 1%. DF: Days to fifty percent flowering, FS: Days to first fruit set, PB: Primary branch per plant, SW: Stem width, FG: Fruit girth, DM: Days to maturity, FL: Fruit length, PL: Pedicel length, PH: Plant height, NFP: number of fruit per plant, IL: Internode length, DFY: Dry fruit yield per plot, rp: Phenotypic correlation.

4.3.2.2. Genotypic direct and indirect effect of various characters on dry fruit yield per plot

The path analysis at the phenotypic level may not provide a true picture of direct and indirect causes (Sood *et al.*, 2009), and it is advisable to understand the contribution of different traits toward the dry fruit yield/plot at the genotypic level. For path analysis at the genotypic level, dry fruit yield/plot was the dependent variable to all other traits used for correlation and considered as casual variables.

The Genotypic direct and indirect effect of different characters on dry fruit pepper yield is presented in Table 12. The maximum positive genotypic direct effect on dry fruit yield per plot was observed in stem width (0.5867) followed by fruit length (0.3671), number of fruit per plant (0.2673), days to fifty percent flowering (0.0956), plant height (0.0754), internode length (0.0026). Negative direct effects were recorded for days to first fruit set (-0.01), primary branch per plant (-0.3273), fruit girth (-0.0145), days to maturity (-0.0646), and pedicel length (-0.0250).

Days to fifty percent flowering (0.0956) had direct positive effect and indirect positive effect through days to first fruit set, stem width, fruit length, plant height, number of fruit per plant and internode length. These results were in accordance with the findings of (Bijalwan and Mishra, 2013 and Shimeles *et al.*, 2016) who reported positive direct effect of days to fifty percent flowering. On the other hand, it had indirect negative effect through primary branch per plant, fruit girth, days to maturity and pedicel length.

Days to first fruit set (-0.01) possess negative direct effect as well as it exerted negative indirect through days to first fruit set, internode length, number of fruit per plant, days to fifty percent flowering, stem width, stem width and plant height. On the other hand days to first fruit set contribute indirect positively through primary branch per plant, fruit girth, days to maturity and pedicel length to dry fruit yield per plot. Days to first fruit set exhibited negative correlation with yield, which is due to negative direct effect as well as negative indirect effect through days to first fruit set, stem width, fruit length, plant height, number of fruit per plant, and internode length.

Primary branch per plant (-0.3273) had negative direct effect and recorded a high positive indirect effect *via* stem width followed by fruit length, number of fruit per plant, days to fifty percent flowering, plant height, days to first fruit set and internode length. It causes negative indirect effect through fruit girth, days to maturity and pedicel length. Similar re-

sults were reported by (Bijalwan and Mishra, 2013; Singh, 2014 and Yattung *et al.*, 2014) for negative direct effect of primary branch per plant. Genotypic correlation analysis indicated primary branch per plant as an important character influencing dry fruit yield. However, path coefficient analysis suggested that primary branch per plant had negative direct effect on yield but had indirect positive influence through stem width, fruit length and number of fruit per plant. The apparent contraction is due to the total correlation measures mutual association without causation whereas path coefficient analysis specifies the causes and measures their relative importance.

Stem width which possess highest correlation (0.994) also exhibit highest direct effect (0.5867) on dry fruit yield per plot. Hence, it would be rewarding to lay emphasis on stem width while developing selection strategies towards high yielding varieties. The indirect contribution of stem width was positive *via* fruit length, number of fruit per plant, days to fifty percent flowering, plant height, days to first fruit set and internode length. In contrast, negative indirect effect was observed by stem width through pedicel length, fruit girth, primary branch per plant and stem width. The highest correlation exhibited by stem width is due to highest direct and indirect effect through fruit length and number of fruit per plant.

Fruit girth exhibited (-0.0145) negative direct effect. Such results have been reported by Sharma *et al.* (2009). The indirect contribution of fruit girth was positive and high *via* stem width and followed by fruit length, number of fruit per plant, days to fifty percent flowering, plant height, days to first fruit set and internode length.

Concerning days to maturity (-0.0646), it had negative direct effect on dry fruit yield per plot. Such results also were reported by (Singh *et al.*, 2014). Its indirect effects through stem width, fruit length, number of fruit per plant, days to fifty percent flowering, plant height, days to first fruit set and internode length were positive. But it exerts negative indirect effect only through primary branch per plant.

The direct effect of fruit length on dry fruit yield per plot was (0.3671) positive. Such results have been reported by (Abraham *et al.*, 2017; Bijalwan and Mishra, 2013; Yattung *et al.*, 2014; Shimeles *et al.*, 2016 and Sing *et al.*, 2014). It had highest positive indirect effect on dry fruit yield per plot through stem width followed by number of fruit per plant, days to fifty percent flowering, plant height, days to fifty percent flowering and internode

length. Also had negative indirect effect on dry fruit yield per plot through primary branch per plant followed by days to maturity, fruit girth and pedicel length. Fruit length and dry fruit yield per plot had highly significant positive correlation which is due to high positive direct effect and indirect effect through stem width and number of fruit per plant as revealed by genotypic path analysis.

Pedicel length had negative direct effect (-0.0250) on dry fruit yield per plot and in direct effect via primary branch per plant and fruit girth. Bijalwan and Mishra (2013 and Sharma *et al.* (2009) reported negative direct effect of pedicel length. On the other way it had positive indirect effect on dry fruit yield per plot through stem width followed by fruit length, number of fruit per plant, days to fifty percent flowering, plant height, days to first fruit set and internode length.

Plant height had positive (0.0754) direct effect on dry fruit yield per plot and indirect positive effect via stem width followed by fruit length, number of fruit per plant, days to fifty percent flowering, days to first fruit set and internode length. Corroborating the findings of present investigation positive direct effect of plant height on yield has also been reported by (Abraham *et al.*, 2017; Bijalwan and Mishra, 2013). Nonetheless, plant height exerted negative indirect effect through primary branch per plant followed by days to maturity and fruit girth.

Number of fruit per plant exerted a positive (0.2673) direct effect. This finding has earlier been supported by (Abraham *et al.*, 2017; Bijalwan and Mishra, 2013; Yattung *et al.*, 2014; Sharma *et al.*, 2009; Shimeles *et al.*, 2016; and Sing *et al.*, 2014). It had positive highest indirect effect through stem width followed by fruit length, days to fifty percent flowering, plant height, days to first fruit set and internode length. In contrast, it exerted negative indirect effect through primary branch per plant followed by days to maturity, fruit girth and pedicel length. Genotypic correlation showed highly significant positive correlation of number of fruit per plant with dry fruit yield per plot. Path analysis revealed that this association is due to positive direct and high positive indirect effect through stem width and fruit length.

Internode length possesses positive (0.0079) direct effect on dry fruit yield per plot. It had positive indirect effect through stem width followed by fruit length, number of fruit per plant, days to fifty percent flowering, plant height and days to first fruit set. In contrast,

internode length exerted negative indirect effect via primary branch per plant followed by days to maturity, fruit girth and pedicel length.

Residual effect genotypic (0.058) level indicated that the traits included in the present investigation accounted for most of the variation (94.2%) present in the dependent variable that is dry fruit yield per plot.

In general, from genotypic path analysis, the number of fruits per plant, stem width, fruit length days to fifty percent flowering, plant height, and internode length exhibited the positive direct effect in which one can improve the dry fruit yield through direct selection of either of these characters during yield improvement program. Moreover, stem width score highest positive direct and indirect effect as a result, it should be given more emphasis in the selection aimed at improving dry fruit yield in chili.

Table 12. Estimates of genotypic direct effects (bold and diagonal) and indirect effects (off diagonal) of traits via other independent

Variable	DF	FS	PB	SW	FG	DM	FL	PL	PH	NFP	IL	rg
DF	0.0956	0.0041	-0.3213	0.5633	-0.0048	-0.0600	0.3567	-0.0049	0.0734	0.2594	0.0034	0.965**
FS	-0.0386	-0.0100	0.1447	-0.2780	0.0068	0.0278	-0.1900	0.0057	-0.0330	-0.1310	-0.0009	-0.497*
PB	0.0938	0.0044	-0.3273	0.5531	-0.0047	-0.0596	0.3549	-0.0033	0.0744	0.2617	0.0028	0.950**
SW	0.0918	0.0048	-0.3086	0.5867	-0.0054	-0.0585	0.3622	-0.0043	0.0702	0.2522	0.0028	0.994**
FG	0.0315	0.0047	-0.1052	0.2189	-0.0145	-0.0196	0.1401	-0.0064	0.0274	0.0935	0.0034	0.373*
DM	0.0888	0.0043	-0.3022	0.5319	-0.0044	-0.0646	0.3392	-0.0006	0.0701	0.2486	0.0032	0.914**
FL	0.0929	0.0052	-0.3164	0.5789	-0.0055	-0.0596	0.3671	-0.0035	0.0720	0.2583	0.0029	0.992**
PL	0.0185	0.0023	-0.0435	0.1010	-0.0037	-0.0016	0.0508	-0.0250	0.0113	0.0369	0.0014	0.148
PH	0.0930	0.0044	-0.3228	0.5462	-0.0053	-0.0600	0.3506	-0.0037	0.0754	0.2638	0.0026	0.944**
NFP	0.0927	0.0049	-0.3204	0.5536	-0.0051	-0.0600	0.3547	-0.0035	0.0744	0.2673	0.0025	0.961**
IL	0.0407	0.0011	-0.1145	0.2096	-0.0062	-0.0258	0.1360	-0.0045	0.0249	0.0842	0.0079	0.353

R = 0.058

* and ** where significant and highly significant at 5% and 1%. DF: Days to fifty percent flowering, FS: Days to first fruit set, PB: Primary branch plant, SW: Stem width, FG: Fruit girth, DM: Days to maturity, FL: Fruit length, PL: Pedicel length, PH: Plant height, NFP: number of fruit per plant, IL: Internode length, rg: genotypic correlation.

5. SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1. Summary

In view of this, the present study investigated with the objective to ascertain the magnitude and extent of genetic variability, and association of agronomic traits among some chili accessions and varieties and their contribution to yield in twenty-six accessions and four varieties. The experiment was conducted in a randomized complete block design with three replications from November 2016 to May 2017 at Tony Farm, Diredawa. The data were subjected to analysis of variance, computation of phenotypic and genotypic coefficients of variation, heritability in broad sense, expected genetic advance, phenotypic, genotypic correlation and path coefficient analysis.

Analysis of variance revealed highly significant ($P \leq 0.01$) mean squares for all traits except for days to fifty percent flowering which is significant at ($p < 0.05$) and fruit girth, pedicel length and plant height which is non-significant. The results indicate that the presence of variability among tested accessions, which are useful for improvement through selection.

A greater phenotypic coefficient of variability (PCV) was observed than genotypic coefficient of the variation (GCV) for all the traits, though the difference was small in some cases. This indicated that the apparent variation is not only due to genotypes but also due to the influence of environment.

The high phenotypic coefficient of variation was observed for primary branch per plant followed by dry fruit yield per plot, fruit length, stem width, number of fruit per plant, plant height and fruit girth. High phenotypic and genotypic coefficients of variations were obtained for primary branch per plant, stem width, fruit length, number of fruit per plant, internode length and fruit dry fruit yield per plot. High genotypic coefficient of variability values of these traits indicates the possibility of improving these traits through selection.

The heritability estimates of traits ranged from 3.86% for fruit girth to 85.62 for primary branch per plant. High heritability estimates were obtained for primary branch per plant followed by fruit length, number of fruit per plant and stem width. The expected genetic advance

as percent of mean varied from 1.79 for fruit girth to 90.65 for primary branch per plant. In the present study, high genetic advance coupled with high heritability was obtained for primary branch per plant, fruit length, number of fruit per plant, stem width and dry fruit yield per plot. Thus, traits that have high heritability along with high genetic advance as percent mean can be improved through selection more easily than the others.

Yield is the result of interaction of a number of inter-related characters. Therefore, selection should be done based on these component characters after assessing their correlation with the yield. Genotypic and phenotypic correlations followed similar trend for most of the characters studied. The genotypic correlations were higher than the phenotypic correlation in most of the cases indicating the high heritable nature of the characters. Dry fruit yield per plot had highly significant and positive genotypic and phenotypic association with days to fifty percent flowering, Primary branch per plant, Stem width, Days to maturity, Fruit length, Plant height and Number of fruits per plant.

The path coefficient analysis at the phenotypic level based on dry fruit yield per plot as dependent variable showed that stem width (0.4059), days to maturity(0.0401), fruit length(0.4293), pedicel length(0.0122), plant height(0.1081), number of fruit per plant(0.2610), and internode length(0.0227) revealed positive direct effect on dry fruit yield per plot. However, Days to fifty percent flowering, days to first fruit setting, primary branch per plot, and fruit girth had negative direct effect on dry fruit yield per plot.

The genotypic path revealed that maximum positive genotypic direct effect on dry fruit yield per plot was observed in stem width(0.5867) followed by fruit length (0.3671), number of fruit per plant (0.2673), days to fifty percent flowering (0.0956), plant height(0.0754), inter node length(0.0026). Negative direct effects were recorded for days to first fruiting, primary branch per plant, fruit girth, days to maturity, pedicel length, and drop per plant.

5.2. Conclusion

The findings indicate that there exists adequate genotypic variation in the accessions and varieties for stem width, primary branch per plant, fruit length, and number of fruit per plant showing high values of PCV, GCV and high heritability coupled with high genetic advance as per cent of mean suggesting predominance of additive gene action and lower influence of environmental factors in the expression of these traits with possibility for improvement through selection.

On the basis of correlation studies at both genotypic and phenotypic level and their coefficient of determination, the selection for Stem width, days to fifty percent flowering, primary branch per plant, days to maturity, fruit length, plant height, and number of fruit per plant will be effective for isolating plants with higher yield in chili.

In view at the direct and indirect contributions of component traits towards fruit yield at genotypic and phenotypic path analysis, selection on the basis of yield related traits viz., stem width, fruit length, plant height, number of fruit per plant, and internode length would be a paying proposition in the accessions and varieties included in the study.

It can also be seen from mean performance value each accessions and varieties that the variety V.AVPP.0411 and accession 9098 gave high dry fruit yield per plot under Diredawa condition indicating their potential to promote for production around Diredawa.

5.3. Recommendations

Considering the above findings of the present experiment and field observation, the following recommendations and suggestions forwarded:

1. From the present study it was noted that stem width had high genetic advance along with heritability, highly significant association with yield at both genotypic as well as phenotypic correlation moreover, it had highest positive direct and indirect effect on yield. Therefore, emphasis should be laid for this trait while selecting genotypes during yield improvement program.

2. This study was carried out with 26 accessions and 4 varieties so more accessions and varieties from different environment should be included for further study.
3. To be conclusive on fair estimation of genetic make-ups and their contribution to phenotypic expression of characters, such evaluation experiments should be conducted over multiple seasons at different locations.
4. This study was done based on phenotypically observable characteristics so, it is advisable to do similar research at molecular level.

6. REFERENCES

- Abrham Shumbulo, Mandefro Nigussie and Sentayehu Alamerew. 2017. Correlation and Path Coefficient Analysis of Hot Pepper (*Capsicum annum* L.) Genotypes for Yield and its Components in Ethiopia. *Advances in Crop Science and Technology*, 5 (3): 1-5.
- Adey Nigatu. 2006. Water use and yield response drop irrigated tomato to soil depletion and mulching. MSc. Thesis presented to school of Graduated studies of Haramaya Univesity.
- Adunga Wakjira and Labuschangne, M.T. 2003. Association of linseed characters and its variability in different environment. *Journal of Agricultural Science*, 14: 285–296.
- Ajjapplavara, P.S. Patil, S.S. Hosamani, R.M. Patil, A.A. and Gangaprasad, S. 2005. Correlation and Path Coefficient Analysis in Chilli. *Karnataka Journal of Agricultural Science*, 18 (3): 748-751.
- Akbar, N., Ahmad, H., Ghafoor, S., Begum, K., Afridi, S.G., Muhammad, I. and Khan, I.A. 2010. Estimation of genetic diversity in capsicum germplasm using randomly amplified polymorphic DNA. *Asian Journal of Agricultural Science*, 2 (2): 53-56.
- Alemu Hailiye and Ermias Abate. 2000. Horticultural crops production and associate constraints in North West Ethiopia. Working paper. Agricultural Economics Research Division. Agricultural Research Center, Adet. Pp 18.
- Al-Jibouri, H. A., Miller, P. A. and Robinson, H. V. 1958. Genotypic and environmental variances and covariances in an upland cotton cross of interspecific origin. *Agronomy Journal*, 50: 633-536.
- Araceli, A.M., Morrell, P. L., Roose, M. L and Kim, S.C. 2009. Genetic diversity and structure in semi wild and domesticated chiles (*Capsicum annum*; Solanaceae) from Mexico, *American Journal of Botany*, 96 (6): 1190–1202.
- Aytac, Z. and Kinaci, G. 2009. Genetic variability and association studies of some quantitative characters in winter rape seed (*Brassica napus* L.), *African Journal of Biotechnology*, 8: 3547-3554.
- Baral, J., and Bosland, P. 2002. Genetic Diversity of a Capsicum Germplasm Collection from Nepal as determined by Randomly Amplified Polymorphic DNA Markers. *Journal of American Society of Horticultural Science*, 127 (3): 316-324.

- Basazen Fantahun. 2006. Genetic Variability and trait associations in some triticale genotypes at Kulumsa and Assasa, Arsi. MSc thesis presented to the school of graduate studies of Haramaya University.
- Bäurle, I. and Laux, T. 2003. Apical meristems: The plant's fountain of youth. *BioEssays: news and reviews in molecular, cellular and developmental biology*, 25 (10): 961–970.
- Berhanu Yadeta, Derbew Belew, Wosene Gebreselassie and Fekadu Marame. 2011. Variability, Heritability, and genetic advance in Hot pepper (*Capsicum annuum* L.) genotypes in West Shoa, Ethiopia. *American Eurasian Journal of Agricultural and Environmental Science*. 10(4): 587-592.
- Bijalwan, P. and Mishra, A.C. 2014. Correlation and Path Coefficient Analysis in Chilli (*Capsicum annuum* L.) for Yield and Yield Attributing Traits. *International Journal of Science and Research*, 2319-7064.
- Bijalwan, P. and Mishra, A.C. 2013. Correlation and Path Coefficient Analysis in Chilli (*Capsicum annuum* L.) for Yield and Yield Attributing Traits. *International Journal of Science and Research*, 5 (3): 1589- 1591.
- Bosland, P. W. and Votava, F. J. 2000. Peppers, Vegetable and Spice Capsicums. CABI Publishing, New York. Pp. 204.
- Burt and Austin. 2000. Perspective: Sex, Recombination, and the Efficacy of Selection Was Weismann Right? *Evolution: International Journal of Organic Evolution* 54(2): 337–351.
- Burton, C.W. and Devane, E. H. 1953. Estimating heritability in tall Festuca (*Restuca arundinaceae*) from donal material. *Agronomy Journal*, 45: 1476-1481.
- Buys, H., Hendricks, M., Eley, B., Hussey, G. 2002. The role of nutrition and micronutrients in pediatric HIV infection. *SAD Journal*, 57:454-456.
- CPI (Chile Pepper Institute) publication. 2007. New Mexico State University.
- CSA (Central Statistical agency). 2011. Agricultural sample survey. Vol. I. Report on area and production of crops.
- Datta, S., and Das, L. 2013. Characterization and Genetic Variability Analysis in *Capsicum annuum* L. Germplasm. *SAARC Journal of Agriculture*, 11 (1): 91-103.

- De Witt, D. and Bosland, P. W. 2009. Complete Chile Pepper Book: A Gardener's Guide to Choosing, Growing, Preserving, and Cooking.
- Demewez Fentie, Getachew Alemayehu, Mahesh Siddalingaiah and Tilahun Tadesse. 2014. Genetic Variability, Heritability and Correlation Coefficient Analysis for Yield and Yield Component Traits in Upland Rice (*Oryza sativa* L.). *East African Journal of Sciences* 8 (2): 147 – 154.
- Dewey, D. R. and Lu, K. H. 1959. A correlation and path coefficient analysis of components of crested wheat grass seed production. *Agronomy Journal*, 51: 515-518.
- Dias, G., Gomes, V., Moraes, T., Zottich, U., Rabelo, G., Carvalho, A and daCunha, M. 2013. Characterization of Capsicum species using anatomical and molecular data. *Genetics and Molecular Research*, 4(2): 1-14.
- Dipendra, G. and Gautam, B. P. 2002. Variability, heritability and genetic advance in chilli (*Capsicum* spp). *Agricultural Science Digest*, 22(2): 102-104.
- EARO (Ethiopian Agricultural research Organization). 2004. Released crop varieties and their recommended cultural practices. Progress report. Addis Ababa, Ethiopia.
- Esayas Kinfu. 2009. Nutritional composition, physicochemical and functional properties of some capsicum varieties grown in Ethiopia. MSc Thesis Master of Science in Food Science and Nutrition. Addis Ababa University. Addis Ababa, Ethiopia.
- Falconer, D. S and Mackay, T. F. C. 1996. *Introduction to Quantitative Genetics. 4th edition.*, Benjamin Cummings, England, ISBN-10: 0582243025.
- FAO (Food and Agriculture Organization). 2009. FAO STAT Database for production of peppers. Rome, Italy.
- Fekadu Marame, Lemma Desalegne, Harjit-Singh, Chemedha Fininsa, Roland Sigvald. 2008. Genetic Components and Heritability of Yield and Yield Related Traits in Hot Pepper. *Research Journal of Agriculture and Biological Sciences*, 4 (6): 803-809.
- Geleta, L., Labuschagne, M. and Viljoen, C. 2005. Genetic variability in pepper (*Capsicum annuum* L.) estimated by morphological data and amplified fragment length polymorphism markers. *Biodiversity Conservation*, 14: 2361-2375.
- Ghosh, S. K. and Gulati, S. C. 2001. Genetic variability and association of yield components in indian mustard. *Crop Resource*. 21 (3): 345-349.

- Gómez, H. B, Moreno, L. M., Sánchez, E.R., Gutiérrez, A. P. and Lugo, G. R. 2013. Morphological characterization of *Capsicum annuum* L. accessions from southern Mexico and their response to the Bemisia tabaci-Begomovirus complex. *Chilean Journal of Agricultural Research*, 73(4).
- Gomez, K. A and Gomez, A. A. 1984. *Statistical procedure for an agricultural research*, 2nd edition. John Wiley and Sons, USA. Pp: 680.
- Grubben, G. J. H. and El-Tahir, I. M. 2004. *Capsicum annuum* L. In: Grubben, G. J. H and Denton, O. A. (eds.). PROTA 2: Vegetables/legumes. (CDRom). PROTA, Wageningen, Netherlands.
- Herman, V.A. 2005. The production of new and improved hot pepper cultivars for the Caribbean, agriculture.gov.bb/files/new%20varieties%20hot%20pepper%20.pdf.
- Hill, T.A., Ashrafi, H., Reyes-Chin-Wo, S., Yao, J., Stoffel, K., Truco, M.A., Kozik, A., Michelmore, R.W and Deynze, A.V. 2013. Characterization of *Capsicum annuum* genetic diversity and population structure based on parallel polymorphism discovery with a 30K Unigene Pepper Gene Chip. *Plos One*, 8 (2): 1-16.
- Janaki, M., Naram, L., Naidu, C., Ramana, V., and Rao, M. P. 2015. Assessment of Genetic Variability, Heritability and Genetic Advance for Quantitative Traits in Chilli (*Capsicum annuum* L.). *International Quarterly Journal of Life Science* 10(2): 729-733.
- Johnson, H.W., Robinson, H.E. and Comstock, R.E. 1955. Estimates of genetic and environmental variability in soybean. *Agronomy Journal*, 47: 314-318.
- Joseph, T. M. 2012. Pattern of Genetic Variability In Nsukka Yellow Pepper (*Capsicum annuum* L.) genotypes. A dissertation submitted to the department of crop science, faculty of agriculture, university of nigeria, nsukka in partial fulfillment of the requirements for the award of the degree of master of science in crop science (plant breeding and genetics).
- Kelley, W. T. and Boyhan, G. 2009. Commercial Pepper Production Handbook. The University of Georgia and Ft. Valley State University.
- Khan, M. H. and Dar, A. N. 2009. Correlation and Path Coefficient Analysis of Some Quantitative Traits in Wheat. *African Crop Science Journal* 18 (1): 9 – 14.

- Khurana, D. S., Singh, P. and Hundal, J. S. 2003. Studies on genetic diversity for growth, yield and quality traits in chilli (*Capsicum annum* L.). *Indian Journal of Horticulture*, 60 (3): 277-282.
- Kumar, B. K., Munshi, A. D., Joshi, S. and Kaur, C. 2003. Note on evaluation of chilli (*Capsicum annum* L.) genotypes for biochemical constituents. *Capsicum and Eggplant Newsletter*, 22: 41-42.
- Kumar, D., Kumar, R., Kumar, S., Bhardwaj, M. L., Thakur, M. C., Kumar, R., Thakur, K. S., Dogra, B. S., Vikram, A., Thakur, A. and Kumar, P. 2013. Genetic Variability, Correlation and Path Coefficient Analysis in Tomato. *International Journal of Vegetable Science*, 19(4): 313-323.
- Kumar, R., Kaushal, S. and Shukla, Y. R. 2010. Variability, Correlation, and Path Analysis Studies in Lettuce. *International Journal of Vegetable Science*, 16: 299–315.
- Kumari, S., Jyothi, U., Reddy, C., Srihari, Sankar, S. and Sankar, R. 2011. Character association in paprika (*Capsicum annum* L.) *Journal of Spices and Aromatic Crops*, 20 (1): 43–47.
- Lavinia, S., Madoșă E., Giancarla, V., Ciulca S., Avădanei C. and Gabriela, G. 2013. Studies regarding correlations between the main morphological traits in a collection of bell pepper (*Capsicum annum* var, *grossum*) local landraces. *Journal of Horticulture, Forestry and Biotechnology*, 17 (2): 285- 289.
- Luitel, B. P., Yoon, C. S., Surendra . Kang, W. H. 2013. Correlation and Path Coefficient Analysis for Fruit Yield and Quality Characters in Segregating Population of Mini-paprika (*Capsicum annum* L.). *Journal of Agricultural, Life and Environmental Sciences*, 25(1).
- Majeed and Prakash, L. 2000. The Medicinal uses of pepper. *International pepper news*, Vol XXV, 1:23-31.
- Manju, P. R. and Sreelathakumary, I. 2002. Genetic Variability, Heritability and Genetic Advance in Hot Chilli (*Capsicum Chinense* Jacq.). *Journal of Tropical Agriculture* 40: 4-6.
- MARC (Melkasa Agricultural Research Center). 2003. Progress Report Addis Ababa.
- Maurya, A. K., Kushwaha, M. L., and Singh, B. K. 2015. Genetic Studies in Chilli (*Capsicum annum* L.). *International Journal of Science & Technology* 2321 – 919.

- Mcmullan, M., and Livsey, J. 2013. "The chileman. Bolivian Gold (PI, 260579): baccatum,". Bolivia, Brazil.
- Meena, O. P. and Bahadur, V. 2013. Assessment of breeding potential of tomato (*Lycopersicon esculentum* Mill.) germplasm using D² analysis. *The Bioscan*. 8(4): 1145-1148.
- Metasebiya Terefe, Tadele Tefera and sakhuja, P. K. 2008. Effect of a formulation of *Bacillus firmus* on root-knot of nematode *Meloidogyne incognita* infestation the growth of tomato plants in the greenhouse and nursery. *Journal of Invertebrate and Pathology*., 100 (2): 94-99.
- Mini, S. and Khader, K. M. A. 2004. Variability, heritability and genetic advance in wax type chilli (*Capsicum annuum* L.). *Capsicum and Eggplant Newsl*, 23: 49-52.
- Mishra, A. C., Singh, R. V. and Ram, H. H. 2004. Studies on genetic variability in capsicum (*Capsicum annuum* L.) under mid hills of Uttaranchal. *Capsicum & Eggplant Newsletter*, 23: 41-44.
- Mohammed, I., Ganiger, V. M. and Yenjerappa, S. T. 2001. Genetic variability, heritability, genetic advance and correlation studies in chilli. *Karnataka Journal of Agricultural Science*, 14(3): 784-787.
- Moscone, E., Baranyi, M., Ebert, I., Greilhuber, J., Ehrendorfer, F., and Hunziker, A. 2003. Analysis of nuclear DNA content in *Capsicum* (Solanaceae) by Flow Cytometry and Feulgen Densitometry. *Annals of Botany*, 92, 21-29.
- Nemati, A., M. Sedghi, R., Seyedsarifi and Seidi. 2009. Investigation of correlation between traits and path analysis of corn (*Zea mays* L.) grain yield at the climate of Ardabil region (Northwest Iran). *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, 37(1): 194- 198.
- Onwubuya, E. A., Okporie, E. O and Nenna, M. G. 2008. Nsukka yellow pepper processing and preservation techniques among women in Enugu State. *African Journal of Agricultural Research*, 4 (9): 859-863.
- Pandit, M. K and Adhikary, S. 2014. Variability and Heritability Estimates in Some Reproductive Characters and Yield in Chilli (*Capsicum annuum* L.). *International Journal of Plant and Soil Science*, 3 (7): 845-853.

- Pawar, S.S., Bharude, N.V., Sonone, R.S., Deshmukh, A.K., Raut and Umkar, A.R. 2011. Chillies As Food, Spice and Medicine: A Perspective. *International Journal of Pharmacy and Biological Sciences*. 311-318.
- Prabhakaran, T. S., Natarajan, S. and Veeraragavatham, D. 2004. Studies on genetic variability, heritability and genetic advance in chilli (*Capsicum annum* L.). *South Indian Horticulture*, 52(1/6): 70-72.
- Prakash, M., Ganesan, J. and Venkatesan, M. 2003, Genetic variability, heritability and genetic advance analysis in cowpea (*Vigna unguiculata* L. Walp). *Legume Res.*, 26: 155-156.
- Rahman, M.J., Uddin, M.S., Bagum, S.A., Mondol, A.T.M.A.I., and Zaman, M.M. 2006. Effects of mulches on the growth and yield of tomato in the coastal area of Bangladesh under rainfed condition. *International Journal of Sustainable Crop Production*, 1: 06 - 10.
- Rathod, H., Saravaiya, S. N., Patel, A. I. and Krishna Patel. 2016. Genetic Variability, Correlation and Path Coefficient Analysis in Tomato (*Solanum Lycopersicum*). *An International Quarterly Journal of Life Science* 11 (3): 1969-1974.
- Robinson, H. F., R. E. Comstock and P. H. Harvey. 1949. Estimates of heritability and the degree of dominance in maize. *Agronomy Journal*, 41: 353-359.
- Rohman, M.M., Iqbal, A.S.M., Arifin, M.S., Akhtar, Z., and Husanuzzaman, M. 2003. Genetic variability, correlation and path analysis in mungbean. *Asian Journal of Plant Sciences*, 2 (17-24): 1209-1211.
- Roukens, O. 2005. Export Potential of Ethiopian Oleoresins. Ethiopian Export Promotion Department, Ethiopia, pp8 - 12.
- Sarker, S. 2013. Studies on the heterosis and combining ability in capsicum (*capsicum annum*). A Thesis Submitted to the Department of Horticulture Sher-e-Bangla Agricultural University, Dhaka in partial fulfillment of the requirements for the degree of Master of Science (MSc.) in Horticulture.
- Sharma, M. and Sridevi, O. 2016. Genetic Variation and Character Association Analysis in Chilli (*Capsicum annum* L.). *An International Quarterly Journal of Life Science*, 11(3): 1675-1678.

- Sharma, V. K., Semwal, C. S. and Uniyal, S. P. 2010. Genetic variability and character association analysis in bell pepper (*Capsicum annuum* L.). *Journal of Horticulture and Forestry*, 2 (3): 058-065.
- Shaukat, S., Raziuddin, Khan, F. U, Khalil, I. A. 2015. Genetic Potential and Heritability Estimates of Yield and Yield Associated Traits in Rape Seed Brassica Napus L. *International Journal of Environment*, 4 (2): 2091-2854.
- Shimeles Aklilu, Bekele Abebie, Dagne Wogari and Adeferis T/Wolde. 2016. Genetic Variability and Association of Characters in Ethiopian Hot Pepper (*Capsicum Annum* L.) Landraces. *Journal of Agricultural Sciences*. 61(1): 19-36.
- Singh, M. D., Laisharam, J. M. and Bhagirath, T. 2005. Genetic variability in local chillies (*Capsicum annuum* L.) of Manipur. *Indian Journal of Horticulture*, 62 (2): 203-205.
- Singh, P. K. Kumar, A. and Ahad, I. 2014. Correlation and path coefficient analysis in yield contributing characters in chilli, *Capsicum annum* L. *International Journal of Farm Sciences* 4(4): 104-111.
- Singh, Y., Sharma, M. and Sharma, A. 2009. Genetic Variation, Association of Characters, and their Direct and Indirect Contributions for Improvement in Chilli Peppers, *International Journal of Vegetable Science*, 15(4): 340-368.
- Singh, Y., Sharma, M. and Sharma, A. 2009. Genetic Variation, Association of Characters, and Their Direct and Indirect Contributions for Improvement in Chilli Peppers, *International Journal of Vegetable Science*, 15(4): 340-368.
- Sivasubramaniam, S and Menon, M. 1973. Heterosis and inbreeding depression in rice. *Madras Agricultural Journal*, 60: 11-39.
- Sonago, S. 2003. Chili pepper and the threat of wilt disease. Online plant Health progress. New Mexico State University Las Cruces, 88003.
- Sonia, S., Bindal, A. K. and Sharma, A. 2006. Genetic variability, heritability and genetic advance of various polygenic traits in Capsicum (*Capsicum annuum* L.). *Scientia Horticulture*, 10: 201-207.
- Sood, S., Sood, R., Sagar, V. & Sharma, K. C. 2009. Genetic Variation and Association Analysis for Fruit Yield, Agronomic and Quality Characters in Bell Pepper. *International Journal of Vegetable Science*, 15 (3): 272-284.

- Sreelathakumary, I and Rajamony, L. 2003. Variability, heritability and genetic advance in bird pepper (*Capsicum frutescens* L.). *Capsicum & Eggplant Newsl*, 22: 51-54.
- Sreelathakumary, I. and Rajamony, L. 2004. Variability, heritability and genetic advance in chilli (*Capsicum annuum* L.). *Journal of Tropical Agriculture.*, 42(1-2): 35-37.
- Sreelathakumary, I., and Rajamony, L. 2002. Variability, heritability and correlation studies in chilli (*Capsicum* spp.) under shade. *Indian Journal of Horticulture*, 59: 77-83.
- Sudre, C.P., Gonçalves, L.S.A., Rodrigues, R., Amaral-Junior, A.T. do., Riva-Souza, E.M. and Bento, C.D.S. 2010. Genetic variability in domesticated capsicum spp as assessed by morphological and agronomical data in mixed statistical analysis. *Genetics and Molecular Research*, 9(1):283-294.
- Tadesse Tilahun. 2013. Genetic Variability and Association of Characters among Green Pod Yield And Yield-Related Traits in Chilies (*Capsicum annuum* L.) Accessions in Ethiopia. A thesis Submitted to College of Natural and Computational Science, Department of Biology, School of Graduate Studies Haramaya University.
- Tamedo Tana, Schutz, W. and Milberg, D. 2000. Germination Ecology of the weed *Parthenium hysterophorus* in Eastern Ethiopia. *Annual Applied Biology*, 140:263-270.
- Verma, S. K., Singh, R. K. and Arya, R. R. 2004. Genetic variability and correlation studies in chillies. *Progressive Horticulture*, 36(1): 113-117.
- Vijaya, H.M., Gowda, A.P. M. and Nehru, S. D. 2014. Genetic variability, correlation coefficient and path analysis in chilli (*Capsicum annuum* L.) genotypes. *Environmental Life Science*, 7 (3): 175- 178.
- Weber, C. R. and Moorthy, B. R. 1952. Heritable and non-heritable relationship and variability of oil content and agronomic characters in the F2 generation of soybean crosses. *Agronomy Journal*, 44: 202-209.
- Yamamoto S. and Nawata E. 2005. *Capsicum Frutescens* L. in Southeast and East Asia and its dispersal routes into Japan. *Economic Botany*, 59: 18-28.
- Yatung, T., Dubey, R., Singh, V., Upadhyay, G. and Ak Pandey. 2014. Selection Parameters for Fruit Yield and Related Traits in Chilli (*Capsicum annuum* L.). *Bangladesh Journal of Botany*, 43 (3): 283-291.

- Yayeh Zewdie, Tong, N. K and Bosland, P. W. 2004. Establishing core collection of *Capsicum* spp. using a cluster analysis with enlightened selections. *Genetic Resources and Crop Evolution*, 51: 147-151.
- Yayeh Zewdie. 1998. Ethiopian Chiles: A deep-rooted tradition. *Chili Pepper Institute*, 8(1): 1-2.
- Zecevic, B., Dordevic, R., Balkaya, A., Damnjanovic, J., Dordevic, M., Vujošević, A. 2011. Influence of parental germplasm for fruit characters in F1, F2 and F3 generations of pepper (*Capsicum annuum* L.). *Genetika*, 43:209-216.
- Zhang, H., Schroder, J.L., Fuharman, J.K., Basta, N.T., Storm, D.E., and Payton, M.E. 2005. Path and multiple regression analyses of phosphorus sorption capacity. *Soil Science Society of America Journal*, 69: 96–106.

7. APPENDICES

Appendix Table 1. Analysis of variance for 12 quantitative traits of the 26 chili accessions and the four varieties evaluated in 2016/2017.

Traits	Mean Square Values			Mean	CV (%)
	Replication	Accession	Error		
Df	2.00	29.00	58.00	-	-
DF	18.30	38.44*	16.44	38.70	10.50
FS	17.68	49.83**	18.33	61.00	7.00
PB	1.44	40.75**	2.16	7.53	19.50
SW	0.68	12.25**	1.59	6.64	19.00
FG	0.28	1.58	1.41	5.39	22.00
DM	2.50	495.60**	138.00	136.40	8.60
FL	0.48	18.58**	1.27	7.17	15.70
PL	0.01	0.41	0.29	2.92	18.50
PH	128.10	171.50	117.70	49.90	21.80
NFP	27.90	513.00**	64.00	48.26	16.60
IL	1.05	5.25	1.66	5.17	24.90
DFY	0.01	0.19	0.02	0.62	25.50

Where,** and* indicate significant differences at 1% and 5%, respectively. DF: Days to first fruit set, PH: Plant height, PBPP: Number of primary branch, DFF: Days to 50% flowering, DM: Days to Maturity, FPP: Number of fruit per plant, FL: Fruit length, FG: fruit girth, SW: Stem Width, DFY: dry fruit yield per plot, IL: Internode length, and CV (%): coefficient of variance.

Appendix Table 2. Mean performance of the 26 chili accessions and the four varieties in relation to different agronomical traits.

Genotype	DFE	DF	PBPP	SW	FG	DM	FL	PL	PH	FPP	IL	FDWPP
9098	43.33	54.33	14.00	9.33	5.83	154.33	10.83	2.50	61.83	68.33	4.70	0.97
229697	35.00	59.33	3.33	3.50	4.83	124.33	4.17	2.50	41.00	35.00	5.60	0.28
229699	34.67	59.67	3.83	4.00	4.17	124.00	4.50	3.00	42.33	35.33	4.00	0.30
229695	34.67	62.00	4.30	4.50	5.17	126.33	4.50	2.67	44.00	37.00	3.73	0.34
28334	43.33	57.33	12.17	9.17	6.50	153.33	10.33	3.50	61.67	67.33	6.50	0.92
229692	43.67	58.33	12.50	8.83	5.00	151.33	10.00	2.83	60.00	66.67	6.53	0.91
9093	36.67	67.33	5.50	6.00	5.00	126.33	6.00	2.67	44.33	40.33	4.80	0.49
9086	35.00	68.67	3.83	3.83	4.33	122.00	4.00	2.67	41.33	35.00	6.67	0.30
9085	36.67	63.33	5.50	6.00	5.50	126.00	6.00	3.00	45.33	40.67	4.60	0.50
229700	43.67	64.67	12.33	9.00	5.00	152.00	10.17	3.00	59.67	62.00	5.23	0.91
21	35.00	66.67	3.83	4.00	5.00	124.00	4.00	3.00	45.67	35.00	3.80	0.30
22	37.00	64.00	5.17	5.50	4.50	126.33	5.50	3.50	45.00	39.33	2.70	0.48
23	44.33	54.33	14.50	9.33	5.33	156.00	11.00	3.17	62.17	70.00	5.20	0.95
9101	45.00	59.00	13.17	9.17	5.83	153.33	10.50	3.33	61.00	67.67	5.93	0.93
9099	33.00	60.00	3.00	3.50	5.83	121.00	4.00	2.67	41.33	33.33	3.40	0.25
9094	40.00	60.33	8.00	8.00	5.50	142.67	8.50	2.50	51.33	55.33	3.90	0.81
9107	39.00	50.33	7.67	7.83	6.83	141.00	8.50	3.33	51.33	53.00	5.97	0.80
9097	41.00	62.33	9.00	8.33	5.00	147.33	9.00	2.50	55.33	60.00	4.50	0.85
9102	38.00	58.67	6.83	7.33	5.50	132.33	8.00	2.83	47.00	46.00	4.30	0.70

Mean Performance (Continued)

Genotype	DFF	DF	PBPP	SW	FG	DM	FL	PL	PH	FPP	IL	FDWPP
230800	37.33	61.33	6.33	6.67	4.50	132.33	7.00	2.67	46.33	41.33	3.87	0.60
8995	35.00	65.33	3.83	4.00	5.83	123.67	4.17	3.00	42.00	34.67	4.80	0.30
9103	41.67	60.33	10.67	8.50	6.17	148.67	9.67	2.83	57.33	61.33	6.67	0.87
238486	37.00	58.67	6.00	6.17	5.50	127.33	6.83	2.50	45.33	39.33	5.53	0.55
9082	35.33	64.00	4.17	4.33	5.83	125.00	4.00	2.67	44.00	37.33	4.60	0.34
9083	43.67	65.33	13.17	9.00	6.00	153.00	10.17	2.50	61.00	63.33	6.70	0.92
28337	42.00	57.33	10.83	8.50	5.83	150.00	9.67	3.50	57.33	63.67	6.03	0.88
230799	37.00	64.00	5.83	6.00	3.67	129.00	5.50	3.17	45.00	41.33	4.20	0.52
9104	38.67	61.00	6.00	6.50	6.50	120.67	6.67	3.83	46.00	40.00	8.00	0.58
39	38.00	63.33	5.50	6.33	5.33	150.00	6.50	2.67	45.00	38.33	8.10	0.53
20208	36.33	60.00	5.17	6.00	5.83	129.33	5.50	3.17	45.00	39.67	4.60	0.46

Where 21, 22, 23, 39 Represent Variety V-Unknown-2, V. Acc No-223654, V.AVPP.0411, V-Acc No 223631 respectively. DF: Days to first fruit set, PH: Plant height, PBPP: Number of primary branch, DFF: Days to 50% flowering, DM: Days to Maturity, FPP: Number of fruit per plant, FL: Fruit length, FG: fruit girth, SW: Stem Width, DFY: dry fruit yield per plot, IL: Internode length, and CV (%): coefficient of variance.

Appendix Table 3. Comparison of different variability parameters with respect to 12 quantitative characters in chili.

Character	Phenotypic Coefficient of Variation			Genotypic coefficient of variation			Heritability			Genetic advance as per cent of mean		
	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High
DFF	-	+	-	+	-	-	-	+	-	+	-	-
DF	+	-	-	+	-	-	-	+	-	+	-	-
PBPP	-	-	+	-	-	+	-	-	+	-	-	+
SW	-	-	+	-	-	+	-	-	+	-	-	+
FG	-	-	+	+	-	-	+	-	-	+	-	-
DM	-	+	-	+	-	-	-	+	-	-	+	-
FL	-	-	+	-	-	+	-	-	+	-	-	+
PL	-	+	-	+	-	-	+	-	-	+	-	-
PH	-	-	+	+	-	-	+	-	-	+	-	-
FPP	-	-	+	-	-	+	-	-	+	-	-	+
IL	-	-	+	-	-	+	-	+	-	-	-	+
FDWPP	-	-	+	-	-	+	-	-	+	-	-	+

Where, DF: Days to first fruit set, PH: Plant height, PBPP: Number of primary branch, DFF: Days to 50% flowering, DM: Days to Maturity, FPP: Number of fruit per plant, FL: Fruit length, FG: fruit girth, SW: Stem Width, DFY: dry fruit yield per plot, IL: Internode length, and CV (%): coefficient of variance.

+: Presence; - : Absence

PCV, GCV, GAM Low: 0-10

Moderate: 10-20

High: >20

Heritability Low: 0-30

Moderate: 30-60

High: >60

