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Field pea Production and constraints in the Highlands of Ethiopia a Review Article

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Abstract: **Field Pea (Pisum sativum L.) is a major cool-season pulse crop in Ethiopia. Field pea has the largest share of area and total national production of all pulses grown in Ethiopia. In Ethiopia, field pea is the major source of protein for poor farmers. The development of varieties for yield and disease resistance is one of the important activities to support farmers and improve the productivity of the crop. Field pea is grown in highland areas of Ethiopia within an altitude of 1800 - 3200 m.a.s.l. In Ethiopia, where the use of improved crop production technologies in general and improved seeds in particular is limited, the lack of technical skill is one of the most important limiting factors in seed production. Field pea covers about 216,786.33 hectares of arable lands with a total production of 3,608,112.40 quintals with average yield of 1.664 t ha^{-1}. It constitutes 12.73% of the total area covered by pulses. Field pea contains 23-25 percent protein. A major disease which limits the productivity of field pea includes Ascochyta blight, Fusarium wilt, downy mildew, rust and powdery mildew. Whereas weed, aphids and storage pests also the major constraint for field pea production in Ethiopia.**

Keywords: **Pisum sativum, GrainYield, Ascochyta blight, Fusarium wilt, and powdery mildew.**

1. INTRODUCTION

Field Pea (Pisum sativum L.) is a major cool-season pulse crop and an essential component of sustainable cropping systems (Nemecek et al., 2008; Duc *et al.*, 2010; Jensen *et al.*, 2012). Field pea (*Pisium sativum* L.) has the largest share of area and total national production of all pulses grown in Ethiopia. They are valuable and cheap sources of protein when consumed with cereals, which are deficient in essential amino acids. Pulses play significant roles in soil fertility restoration and in export market. Despite their importance, however, production and productivity are far below the potentials due to several factors including the insufficient supply of seeds of improved varieties.

A number of improved field pea varieties have been released for the last two decades. The current Extension Package Program at the national level made farmers aware of the importance of improved seeds of various crops. Despite all these, seeds of improved field pea varieties are not yet sufficiently made available to the needy farmers. It is believed that more varieties will be released from research and the demand for high quality seed is expected to increase because more farmers will realize the benefits of the use of quality seeds.

In Ethiopia, where the use of improved crop production technologies in general and improved seeds in particular is limited, the lack of technical skill is one of the most important limiting factors in seed production. Significant agro-ecological services linked with its ability to develop symbiotic nitrogen fixation as well as its role as a break crop for pest and pathogen pressure reduction have been described (Gemechu *et al.*, 2016;Nemecek and Kägi, 2007; Hayer *et al.*, 2010; Macwilliam *et al.*, 2014). The center of origin for field pea is considered the Mediterranean to central Asia as well as the highlands of Ethiopia Davies, (1976). In Ethiopia field pea is cultivated since ancient time Dawit *et al*., (1994) and its wild and primitive forms of the species were concealed in the highlands of Ethiopia. Due to this fact Ethiopia considered as one of the centers of diversity for field pea. Field pea grow around the world for its fresh green seeds, tender green pods, dried seeds, and soil restorative purposes (McPhee, 2003). Field pea ranked as fourth largest in the world in volume of production in 2014 with 17.4 and 11.2 million tons of green and dry peas respectively, after soybean, groundnut and common bean.

Pea seeds are an important source of proteins and provide an exceptionally varied nutrient profile (for a review, Burstin *et al*., (2011): major constituents are starch (from 18.6 to 54.1%) and proteins (15.8–32.1%), followed by fibers (5.9–12.7%), sucrose (1.3–2.1%), and oil (0.6–5.5%). Seeds also contain minerals, vitamins, and micro-nutrients such as polyphenolics, saponins, α-galactosides, and phytic acids whose health-promoting effects are being tested (Bastianelli *et al*., 1998; Mitchell *et al.*, 2009; Dahl *et al*., 2012; Marles *et al.*, 2013; Arnoldi *et al.*, 2015). Peas enter in human nutrition in a wide diversity of forms: fresh seedlings, immature pods, and seeds provide a green vegetable, and whole or ground dry seeds are cooked in various dishes. High quality starch, protein, or oligoside isolates are being extracted from dry pea seeds and whole seed structural and functional characteristics have been assessed for food improvement Brummer *et al.*, (2015). Because dry seeds contain little anti-nutritional factors, they are also introduced as a protein source mainly in monogastric diets without affecting growth and production traits (Stein *et al*., 2006; Laudadio *et al*., 2012; Dotas *et al.*, 2014). Pea hay is used as fodder in ruminant diets Bastida Garcia *et al*., (2011).

In Ethiopia, *Pisum sativum var.sativum* is grown in high altitude area (1800-3200) m.a.s.l Haddis Yirga *et al*., (2013). Among the highland pulse crops Field pea is the third most important staple food legume crop in Ethiopia next to faba bean and common bean, among the highland pulses. Field pea covers about 216,786.33 hectares of arable lands with a total production of 3,608,112.40 quintals with average yield of 1.664 t ha^{-1}. It constitutes 12.73% of the total area covered by pulses CSA, (2019).

In Ethiopia, field pea is mainly used to prepare "*shiro wet*", a stew eaten with local bread made of teff, i.e. "*Injera*". The crop is commonly grown in association with faba bean (*Vicia faba*), and is important food, cash and "hunger break" crop in highlands of the country. Field pea supplies 344 calories, 20.1 g protein and 64.8 g carbohydrates/100g edible portion Asfaw *et l*., (1994). It is known as poor man's meat in the developing world since it provides valuable cheap protein. In combination with wheat, rice and other cereals it provides a balanced diet Santalla *et al*., (2001) though pea protein is deficient in sulphur- containing amino acids (Cysteine and methionine) McPhee, (2003).

Despite the importance of field pea in Ethiopia, the major yield-limiting constraints in field pea production in Ethiopia are aphids, low yielding local varieties, lodging, diseases (ascochyta blight, powdery mildew), and pod shattering. This fungus spread locally with air currents, whereas rain controls the disease by washing off spores and making them burst instead of germinating Hargedorn, (1991). The most preferable management measure against the pathogen is developing resistant varieties Sharma, (1995). The high diversity of the field pea accession associated with the robust representation of its center of domestication, that is, the Near East and Mediterranean Warkentin *et al*., (2015) and other centers of diversity, including Central Asia and Ethiopia Van der Maesen *et al*., (1988).

The existence of wide range of field pea germplasm in Ethiopia makes the country the secondary center of genetic diversity Gemechu *et al.*, (2012). Some scholars also considered the high elevation of Ethiopia within the range of the center of origin of the crop. This indicates that has Ethiopia the potential for improving field pea for desired traits either through selection and/or hybridization breeding programs.

Genetic variability is the key factor for the success of any breeding program. In field pea, studies showed that the landraces and accessions in the breeding programs are focused on selection and evaluation from the existing diversity (Smýkal *et al*., 2011; Burstin *et al*., 2015). That indicates the great potential for the breeding program. Even selection among a diverse population provide a certain amount of success in the breeding program, crossing will be essential to combine to different contrasting genotypes to produce a hybrid that combine the trait of interest and produce heterosis (Arunachalam and Bandyopadhyay, 1984; Reddy, 1988; Singh, 1990; Wallace and Yan 1998; Chahal and Gosal, 2002).

The crossing among the highly divergent parents can produce varieties with broad genetic base (Russell, 1978; Chandel and Joshi, 1983; Singh, 1990; Gemechu *et al*., 1997) and raises the yield ceilings imposed by a narrow genetic base (Chandel and Joshi, 1983).

The national field pea program conducted research activities and released about 40 varieties, still now these varieties did not address the production constraints of field pea in the country MOANR, (2016). So, to design appropriate breeding strategy assessing the genetic variability and estimating the genetic parameters (heritability of traits) in the base population will be prerequisite since it is the base to get high yielding; biotic and abiotic stress tolerant varieties. In addition, assessing the genotype x environment interaction will be crucial since most of the traits are governed through polygenic inheritance that affected mostly by the environment (Legesse, 2015; Benti *et al,* 2017).

Besides to plan appropriate selection method understanding the association among traits and its effect on the target trait (like yield) will be important. Yield it is highly affected by different yield component traits that required a clear understanding how these traits affect yield and designing a selection procedure. This indicate sometimes direct selection for the target trait (grain yield) which is a polygenic trait may not be effective in a unless yield contributing traits are considered during selection Srivastava *et al.*, (2017). So, to have a successful breeding program, the breeder should study the genetic variability of the base population, understand the nature of inheritance of the traits and understand the interrelationship among traits of interest to design the breeding strategy. Despite the large number of filed pea accessions held in the gene bank of Ethiopia, Limited information available on the magnitude and pattern of genetic variability for these materials.

2. ORIGIN AND DISTRIBUTION OF FIELD PEA

The origin and progenitors of field pea are not well known. The Mediterranean region, Western and Central Asia, and Ethiopia have been indicated as centers of origin (Blix, 1970). Ethiopia and Western Asia considered as a primary center of diversity, whereas Southern Asia, and South and East Mediterranean regions as secondary centers of diversity FAO, (1998). Pea was domesticated by Neolithic farmers in the Fertile Crescent some 10,000 years ago (Willcox *et al.*, 2009; Weiss and Zohary, 2011; Smýkal, *et al.*, 2014). Field Pea then spread rapidly toward south-west Asia, the Mediterranean basin, and Europe Zohary, (1999). Probably linked with their large range of cultivation and the diversity of their use as food, feed, or fodder, pea landraces and varieties now exhibit an incredible diversity of forms and growing types, adapted to diverse environments, cropping systems, and end-uses Burstin *et al.*, (2015).

This vast diversity of cultivated forms is the major reservoir for present crop improvement. Different types of pea varieties have been developed for vegetable pea production, varying at major genes controlling seed and plant traits. For example, wrinkled seeds are associated with significant changes of seed composition, linked with starch synthesis modification (Wang *et al.*, 2003). Various types of dry peas are also available that differ by their cotyledon color, plant architecture, or flowering time. In addition to this cultivated reservoir of diversity, wild peas can be crossed with cultivated peas. (Ben-Ze'Ev and Zohary (1973) showed that chromosomal rearrangements among accessions from the different Pisum species and subspecies could cause partial sterility in hybrids. Recently, Bogdanova *et al.* (2014) have identified a nucleo-cytoplasmic incompatibility between a P. sativum elatius accession and cultivated peas.

However, within the Pisum genus, wild P. fulvum, wild subspecies P. sativum elatius, and P. sativum humile as well as P. abyssinicum, a tax on cultivated in Ethiopia, are in most cases inter-crossable with P. sativum sativum as long as the cultivated pea is used as female donor (Ben-Ze'Ev and Zohary, 1973; Ochatt *et al.*, 2004). Different authors have thus used P. fulvum as well as wild P. sativum subspecies as a source of alleles for important breeding traits, such as resistance to various fungal diseases (Barilli *et al.*, 2010; Fondevilla *et al.*, 2011; Jha *et al.*, 2012) or to Bruchus pisorum L. Clement *et al.*, (2009).

At present, field pea is cultivated in all temperate countries and most tropical highlands. Field pea is extensively grown in the highlands of eastern Central Africa, East Africa (notably Ethiopia), in southern Africa and parts of Rwanda and Uganda. Field pea is barley grown in West Africa Messiaen *et al.*, (2006). Although field pea is one of the oldest cultivated plants, improving the yield of this crop given little attention as compared to other legume crops (Sultana *et al.*, 2002; Gemechu *et al*., 2013).

2.1. Taxonomy

Field pea is categorized as a Fabaceae (Leguminosae) family and genus *Pisum*. There are three species like *P. fulvum*, *P. abyssinicum* and *P. sativumm* Martin-Sanz *et al.*, (2011). However, according to Thulin (1989) flora volume 3, the species have two varieties that is distributed from Mediterranean region to West Asia. Namely they are *P. sativum* var *sativum* and *P. sativum* var *abyssinicum*.

2.2. Botanical Description

Field pea is an annual plant that is climbing and herbaceous Daisy, (1979). The stems range from dwarf, medium and tall which are 15-90 cm, 90-150 cm and 150-300 cm respectively. Stems angular-terete, slender, with no or few basal branches; internodes hollow and sometimes purple at base. Leaves are alternate and pinnately compound. The leaflets are ovate, entire, 1.5 – 6 cm long and 1-4cm broad. Leaflets opposite or sub-opposite, short-petioluled, ovate or obovate, sometimes more or less rhomboid and asymmetrical. Leaflets are essentially sessile. The stipules are large, up to 10cm long (usually 1.5-8 cm), on round, slender, and glabrous stems. The midrib of the leaf rachis can be slightly winged. This plant climbs using the tendrils produced at the apex of a compound leaf. These modified terminal leaflets form a branched tendril Westphal, (1974).

Semi-leafless pea is also found that caused due to the mutant gene that converts normal leaflets to tendrils. This mutation improves the inter-plant binding and mutual support to produce the erect plant that reduce lodging and harvesting problems. The semi-leafless type has yielded well in evaluation trials, particularly under dry land conditions where its yields have been significantly better than conventional cultivars. The mutants have peculiar advantage for using efficiently the limited water supplies than conventional field peas.

The inflorescence is axillary, solitary, or in 2-3 flowering racemes. The flower are large, butterfly like, usually white but may also be pink or purple and mostly the flowers are self-pollinated. Flowers have 5 sepals, 5 zygomorphic petals (bilaterally symmetrical), 10 stamens in two groups (9 fused + 1 free) and a single superior carpel. The standard petal is obovate, 1.6-3cm long and the glabrous ovary is nearly sessile Daisy, (1979).

Pod is oblong. The color of the pod may vary from yellowish-green to dark- green. Seeds are smooth or slightly wrinkled, 6-8 mm in diameter, white with an orange tinge, green, orange-brown to brown, dark violet, green or brown with violet spots, or with mosaic pattern. Hilum small, elliptic, light colored, sometimes black. Cotyledons light yellow Westphal, (1974). Nevertheless Dekoko differ markedly from field pea. It has leaves with on pair of leaflet and reddish-purple flower and sweeter seeds with black hilum Daisy, (1979).

3. USES

Field pea is primarily used for human consumption or as a livestock feed. Field pea is a grain legume commonly used throughout the world in human cereal grain diets. Field pea has high levels of amino acids, lysine and tryptophan, which are relatively low in cereal grains. Field pea contains 23-25 percent protein. Peas contain high levels of carbohydrates, are low in fiber and contain 86-87 percent total digestible nutrients, which makes them an excellent livestock feed. Field pea contains 5 to 20 percent less of the trypsin inhibitors than soybean. This allows it to be directly fed to livestock without having to go through the extrusion heating process. Field pea is often cracked or ground and added to cereal grain rations.

4. ADAPTATION

Field pea (*Pissum sativum* L.) is a cool season legume crop that is adapted to cool moist climate with moderate temperature. There are two main types of field pea. One type has normal leaves and vine lengths of three to six feet; the second type is the semi-leafless type that has modified leaflets reduced to tendrils, resulting in shorter vine lengths of two to four feet. Pea normally has a single stem but can branch from nodes below the first flower. Most varieties of pea produce white to reddish-purple

Flowers, which are self-pollinated. Each flower will produce a pod containing four to nine seeds. Pea varieties either have indeterminate or determinate flowering habit. Indeterminate flowering varieties will flower for long periods and ripening can be prolonged under cool, wet conditions. Field pea is sensitive to heat stress at flowering, which can reduce pod and seed set. Indeterminate varieties are more likely to compensate for periods of hot, dry weather and are more adapted to arid regions. Determinate, semi-leafless varieties that have good harvest ability are more adapted to the wetter regions.

In the highlands of Ethiopia, field pea is the second most important stable cool-season food legume. It grows in north, south, west, and central parts of the country including pocket areas of the highland and mid highlands with an altitude range from 1800 – 3000 m.a.s.l. Benti (2019) and Kedir (2020).

Field pea is a cheap source of protein (23 to 25%), carbohydrates (12%), vitamins A and C, calcium and phosphorus, apart from having a small quantity of iron Benti *et al*., (2017). Field peas being very rich in proteins, it is valuable for vegetable purposes. This crop has important ecological and economic advantages in the highlands of Ethiopia, as it plays

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a significant role in soil fertility restoration due to its nitrogen fixing ability and also serves as a crop rotation crop to break the mono-cropping practices that has the negative impact on the environment Gemechu *et al*., (2013).

Field pea is the second major pulse crop cultivated in Ethiopia next to faba bean *(Vicia faba* L.). The enhanced legume production can create opportunities for local value-added processing, stimulate domestic demand, and provide off-farm employment, sources of income, and enriched diet for resource-poor and smallholder farmers Getachew (2019). Even if it has multiple benefits in the economic lives of the farming communities, the average yield of the crop is only 1.664 t ha-^{1} in Ethiopia (CSA, 2019) that is far below the potential 4.0 to 5.0 t ha^{-1} traditionally achieved in Europe (Belgium, France and Netherlands) and the worldwide average yield of 1.7 t ha^{-1} Petr *et al*., (2012).

The major reason for this low productivity is lack of resistant varieties to biotic and abiotic stresses and the large gap on yield obtained in research center and farmers land should be minimized. The breeders and farmers do not give attention when compare to cereal crops. So, to fill the gap and feed the increasing population designing effective breeding program that can exploit the existing genetic variability in the genotypes is paramount importance. To achieve this, understanding the nature and degree of divergence in genotypes, the extent of inheritance of the given trait and their interaction with environments are extremely valuable (Johnson *et al*., 1995; Nisar *et al*., 2008).

5. VARIETIES, TYPES AND PERFORMANCE

Selecting the appropriate field pea variety should be based on review of the many differences that exist among varieties. Factors to consider should include market class, yield potential, harvest ease, vine length, maturity, seed size and disease tolerance.

Field pea breeding started in 1960's with the objective of developing highly productive and tolerant cultivars under different agro-ecologies of the country Tamene *et al.*, (2013). With this effort different varieties released for cultivation in different environments of the country. Progress also done to improving the productivity of the crop in the country Teshome, (2011).

The federal and regional research centers engaged in the breeding of field pea doing their best and released suitable varieties in their mandate areas were released in the meantime (Tadele and Edosa, 2009; Mulusew *et al*.,2010; Cherinet and Tazebachew, 2015; Awol *et al.* (2016), MOA and NR, (2016) and Kedir, (2020).

Table 1: List of recommended and released varieties of Field pea

Item No	Name of Variety	Item No	Name of Variety
1	FP DZ	22	Milkiy
2	Mohanderfer	23	NC 95
3	G22 763-2C	24	Holeta
4	Gume	25	Haik
5	Tegegnech	26	Hursa
6	Wolmera	27	Tulu-dimtu
7	Hassabie	28	Arjo-1
8	Adi	29	Bariso
9	Markos	30	Bamo
10	Megeri	31	Ambericho
11	Adet-1	32	Meti
12	Sefinesh	33	Senk
13	Holeta 90	34	Gedo-1
14	Burkitu	35	Tashale
15	Bursa	36	Harana
16	Agrit	37	Weyib
17	Lettu	38	Hortu
18	Weyitu	39	Yewaginesh
19	Dadimos	40	Jiidhaa
20	Tullushenen	41	Jeldu
21	Urji	42	Lammiif

6. FIELD SELECTION

Field pea can be grown on a wide range of soil types, from light sandy to heavy clay. Field pea has moisture requirements similar to those of cereal grains. However, peas have lower tolerance to saline and water-logged soil conditions than cereal grains.

Seed production should be undertaken where soils and climatic conditions are favourable for good crop production. Each variety should be produced in areas of its best adaptation in order to harvest quality seeds. The accessibility of the seed production field to transport and proximity to seed processing plants is also equally important in site selection for seed production so that the seeds of the varieties can be economically produced. The presence of irrigation water and facilities is very important to avoid risks of moisture shortage at any stage of crop growth.

Field peas are most often grown on re-crop following small grain. Being a legume, field pea will fix the majority of required nitrogen if the seed is properly inoculated. Residual nitrogen will also be present for the succeeding crop.

7. SEEDING

Field pea can be grown in a no-till or conventional-till cropping system. Avoid excessive tillage in the spring to avoid drying out the seedbed. Pea seed requires considerably higher amounts of moisture for germination than cereal grains. Field peas are typically seeded in narrow row spacing's 5cm between plant and 20cm between rows. A conventional grain drill or air seeder that is capable of handling large seed without cracking is essential. Field pea should be seeded June to early July.

Seeding pea well into moisture is critical and seeding peas into dry soil should be avoided. Seeding depth of 5cm is recommended.

8. SEEDING RATE

Field pea do not require a fine seedbed as such and hence only 2-3 plowings with the local plow or one disc plowing followed by two disc-harrowing is enough. It is an advantage if land preparation can start early to encourage weed seeds to germinate so that it can be destroyed in subsequent cultivation.

Generally, timely sowing is essential for optimum yields since late sown crops can run into the periods of low moisture and heavy aphid infestation in the mid altitude and frost in the high altitude areas. In the main season sowing one to two week of June in mid altitude and last week of June to first week of July in the high altitude areas are recommended based on the onset of rainfall. Where lodging is suspected, it is advisable to use 10% less fertilizer and slightly less seed rate than the commercial recommendation. The desired plant population is roughly 250,000 plants for field pea per hectare and this can be achieved by setting the seed rates. Seed rates can be calculated by taking into account the size of the seed, germination percentage and expected field loss due to birds, soil borne diseases and insects, etc. as indicated below:

$$\text{Seed Rate (Kg/ha)} = \frac{10{,}000 \times \text{required plants}/m^2}{\text{Number of seeds/kg}} \times \frac{100}{\%\ \text{germination}} \times \frac{100}{100\text{-expected field loss}}$$

9. FERTILIZATION

Under most conditions, the use of inoculants will satisfy the nitrogen requirement of a field pea crop. A soil test should be conducted to determine the status of the primary nutrients. Producers should avoid planting field pea on fields that have a high level of nitrogen. Excess nitrogen will promote Vegetative development over reproductive seed production. Higher nitrogen levels will also reduce the potential of nitrogen fixation and increase the potential for lodging. Research has indicated the importance of adequate phosphorus fertility for optimizing seed yield. Proper fertilizer source, rate and placement are necessary to avoid reductions in plant stand while at the same time meeting the phosphorus needs of the field pea plant. Avoid placing fertilizer directly with the seed. In general 121kg/ha of NPS fertilizer is recommended for field pea in Ethiopia.

10. CONSTRAINTS OF FIELD PEA IN ETHIOPIA

10.1. Diseases in Field pea:

A number of authors (Hagedorn, 1991; Seid, 2015) stated that field peas are subject to a number of diseases, several of which may cause serious injury or loss. Annual losses from diseases vary from year to year, depending often on local weather conditions. Major diseases of field pea include Ascochyta blight, Fusarium wilt, downy mildew, rust and powdery mildew. The spread of diseases caused by fungi and bacteria can be carried out through insects, infected seed, drainage water, refuse and stable manure, farm animals and implements, and wind. It contributes to grain yield instability and reduces farmers' confidence in growing field pea. It occurs in major field pea growing areas. This disease causes stem, leaf and pod spot on the mature plant and foot rot on seedlings. Yield losses on field pea due to this disease were reported to be 50-75% in USA, 45% in England, 33% in Canada and20-53% in Ethiopia.

10.1.1. Ascochyta diseases:

Ascochyta blight more commonly known as "black spot disease" is one of the most severe diseases of field peas, and it is distributed worldwide, including almost all of the major pea-growing areas. Ascochyta blight, an infection caused by a complex of *Ascochyta pinodes*, *Ascochyta pinodella*, *Ascochyta pisi*, and/or *Phoma koolunga*, is a destructive disease in many field peas (*Pisum sativum* L.)-growing regions and it causes significant losses in grain yield. Diseases, particularly, Ascochyta blight (Ascochytapisi), Powdery and downy mildew (Erysiphepolygoni) are the major constraints, causing substantial yield loss and instability in yield. Powdery mildew and Ascochyta blight has been reported to be the major field pea disease in the mid altitudes and may reduce yield by 20-30% under moderate severity Benti (2019).

10.1.2. Powdery mildew

The disease is caused by a fungus parasite *(Erysiphe pisi)*, which is characterized by the formation of a white, powdery, dust like coating on the surface of the leaves and less frequently on the petioles of the leaves, stems, and pods. The leaves are yellowed, dwarfed, and sometimes considerably malformed. The first symptom occurs on the upper foliage. The absence of rain and presence even slight dew favors disease development. Rain can control the disease by washing away spores. Powdery mildew disease affects the yield potential, causing 86% loss in field pea germplasm growing in different parts of the world. 20-30% of field pea yield reduction has been reported by powdery mildew disease in the mid-altitudes under moderate severity Nisar *et al.*, (2006).

Powdery mildew is a troublesome disease when days are warm and dry; nights are cool enough for dew formation. It causes yield loss up to 37% in Ethiopia. This disease is of less effect in high rainfall areas of Ethiopia where its spores are removed from the plant tissue by rain and cannot cause infection. However, late sown and off-season fields were reported to be severely affected by the disease Mussa *et al.*, (2009). 21.09% of yield losses have been reported due to powdery mildew severity on local field pea cultivar from plot without fungicide application at Sinana South Eastern Ethiopia Teshome *et al.*, (2017).

11. WEED CONTROL

Field pea is a poor competitor with weeds, especially during the first month after planting. Relatively slow early-season growth and lack of complete ground cover by the crop canopy allow weeds to be competitive. Field pea is most competitive with even, rapid emergence. A

Well-established stand of seven to eight plants per square foot is critical for field pea to be competitive with weeds. Good weed control is also very important in raising high-quality human edible pea. Cultural methods that should be used as part of an integrated weed management system include crop rotation, field selection, rapid crop establishment at an adequate density and use of clean seed. Pre-emergence or early post-emergence tillage with a rotary hoe or harrow can reduce populations of shallow-emerging weeds. Post-emergence tillage with a rotary hoe or light spring-tooth harrow needs to be timed to control emerging weeds on small (half- to two-inch tall) field pea. Pea stand reduction probably will occur with post-emergence tillage. There are several soil-applied and post-emergence herbicides labeled for weed control in field pea. Generally, post-emergence herbicides should be applied to small weeds and pea (two- to four-inch height) to maximize weed control and minimize crop injury. Pre-harvest desiccants also are labeled to dry weeds for a more efficient harvest.

12. HARVESTING AND THRESHING

Late harvesting may result in shedding and rotting of pods if untimely rain is encountered and in shattering of the seeds. Therefore, harvesting should be done at the appropriate stages when the leaves and the pods dry out and when the grain moisture content is significantly reduced. Under our condition where time of harvesting more or less exactly coincides with the start of the dry season, it is easily possible to achieve low moisture contents while the crop is in the field.

The crops are not as such suitable for combine harvesting and simultaneous threshing and harvesting is may be economically performed using manual labour where labour is available and cheap. The crops should be protected from rain after harvesting while in the field with the use of canvases and polythene sheets. Field pea is indeterminate in growth habit that the lower pods mature earlier when the upper ones are still green. Therefore, the freshly cut crops should be left on the ground and after well-dried (may be three to four weeks after) the crops should be fed to a stationary thresher to get clean seeds. The threshing floor (for both formal and informal seed production) should be clean and preferably cemented to keep contamination by inert matter, weed seeds and other crop/variety seeds to a minimum.

13. SEED PROCESSING

Raw seed usually constitutes unwanted components like impurities both in physical and genetic terms. Therefore, seed processing plant, which includes the process of drying to optimum moisture level for storage, cleaning and grading, testing for purity and germination, treating for storage pests and seed borne diseases, and bagging and labelling, is a largest investment in itself.

The initial moisture content of the seed highly influences the viability of the seed and drying must be started within a few hours after harvesting and threshing and continue until the required optimum moisture level is achieved. Optimum moisture content reduces the deterioration rates during storage, prevents attack by moulds and insects and facilitates processing. Improved seeds of highland pulses should be dried to a moisture content of nearly 9% by thinly spreading on trays or floors in the open sun before storage. Seeds may also be dried artificially by passing heated or unheated air through the seeds to remove moisture but this method is more expensive than natural drying although it is a must especially under a warm, rainy and humid environments.

Seed moisture content is basically determined as per cent water content of the seeds. It is measured either by drying seed samples in an oven or with the help of moisture testers. The oven method involves weighing the seed samples and drying them to a constant weight in an oven. The dried seeds are weighed again and any loss in weight represents the weight of water lost due to drying. Then the percentage moisture content is estimated as:

$$\text{Moisture content (\%)} = \frac{W1 - W2}{W1} \times 100$$

Where W1 is the weight of the seed sample before drying and W2 is the weight of the seed sample after drying. The use of moisture meters may require calibrations and correction factors which may need some technical skill. However, it is the most efficient and faster method.

Seeds after being harvested have to be cleaned to remove inert matter, weed and other crop seeds, other varieties seeds and diseased and damaged seeds. Cleaning enhances seed quality like purity, germination and health provided that the right machines are used and right operations are followed. Seed cleaning is primarily based on the differences in physical properties between the desirable seed and contaminants. Cleaning is possible because seeds are different in physical properties like size, weight and shape. Sieves mainly made of iron are used for cleaning and they mainly separate based on the width and thickness of the seeds. There are also air separators separate seeds mainly according to their weight in relation to the air resistance. Certain particles (dust, chaff, empty or partially filled seeds, husks) will be transported whereas the heavier seed will fall down through the air stream. Use of graded seeds is also obviously an important requirement where sowing is done using seed drills and planters. Seeds should be properly graded before being distributed to the farmers.

14. SEED STORAGE

Seeds should be stored in a dry and cool place free of pests and somehow be protected from absorbing moisture from the floor. Seeds should be treated with proper chemicals for storage pests but care must be taken that the treatment of the seed with improper chemicals may impair the ability of the seed to germinate. The chemical treatment of the seed immediately after harvest and the fumigation of the store before storage are advisable to keep the quality of the seed in storage. The most important storage pest in field pea in Ethiopia is the bean bruchids (*Callosobruchus chinensis)*. Currently, the effective control measure recommended for bean bruchids is the use of Primiphos-methyl (Actelic 50% EC) at the rate of 40g/100kg (6-8 ppm).

15. CONCLUSION

The objective of this review was to increase the product and productivity of field pea and to meet the increasing food requirements of people. Field pea is primarily used for human consumption or as a livestock feed. Field pea is a grain legume commonly used throughout the world in human cereal grain diets. Field pea has high levels of amino acids, lysine and tryptophan, which are relatively low in cereal grains. Field pea contains 23-25 percent protein. Peas contain high levels of carbohydrates, are low in fiber and contain 86-87 percent total digestible nutrients, which makes them an excellent livestock feed. is a cool season legume crop that is adapted to cool moist climate with moderate temperature. There are two main types of field pea. One type has normal leaves and vine lengths of three to six feet; the second type is the semi-leafless type that has modified leaflets reduced to tendrils, resulting in shorter vine lengths of two to four feet. Field pea can be grown on a wide range of soil types, from light sandy to heavy clay. Field pea has moisture requirements similar to those of cereal grains. However, peas have lower tolerance to saline and water-logged soil conditions than cereal grains. Pea seed requires considerably higher amounts of moisture for germination than cereal grains. Field peas are typically seeded in narrow row spacing’s 5cm between plant and 20cm between rows. Field pea do not require a fine seedbed as such and hence only 2-3 plowings with the local plow or one disc plowing followed by two disc-harrowing is enough. It is an advantage if land preparation can start early to encourage weed seeds to germinate so that it can be destroyed in subsequent cultivation.

Field pea covers about 216,786.33 hectares of arable lands with a total production of 3,608,112.40 quintals with average yield of 1.664 t ha^{-1}. It constitutes 12.73% of the total area covered by pulses. Field pea contains 23-25 percent protein. Major diseases of field pea include Ascochyta blight, Fusarium wilt, downy mildew, rust and powdery mildew. Whereas weed, aphids and storage pests also the major constraint for field pea production in Ethiopia.

REFERENCES

[1] Arnoldi A., Zanoni C., Lammi C., Boschin G. (2015). The role of grain legumes in the prevention of hypercholesterolemia and hypertension. CRC. Crit. Rev. Plant Sci. 34, 144–168. 10.1080/07352689.2014.897908

[2] Arunachalam, V., Bandyopadhyay, A. (1984). Limits of genetic divergence for occurrence of heterosis-experimental evidence from crop plants. *Indian J. Genet*.44548554

[3] Asfaw Telaye, Beyene Demtsu and Tesfaye Getachew. (1994). Genetics and breeding of field pea.In cool-season Food Legumes of Ethiopia, Asfaw, T. (Ed). ICARDA. Alepo, Syria, PP: 122-137.

[4] Awol Mohammed, Seyoum Asefie, Wondesen Dagnachew and Niguse Seyum. (2016). Participatory evaluations of field pea varieties in Wollo, Ethiopia (*Pisum sativum* L.). *Journal of Agricultural Science* 1(2): 1-6.

[5] Barilli E., Satovic Z., Rubiales D., Torres A. M. (2010). Mapping of quantitative trait loci controlling partial resistance against rust incited by *Uromyces pisi* (Pers.) Wint. in a Pisum fulvum L. intraspecific cross. Euphytica 175, 151–159. 10.1007/s10681-010-0141-z [CrossRef] [Google Scholar]

[6] Bastianelli D., Grosjean F., Peyronnet C., Duparque M., Regnier J. M. (1998). Feeding value of pea (*Pisum sativum*, L.) - 1 Chemical composition of different categories of pea. Anim. Sci. 67, 609–619. 10.1017/S1357729800033051 [CrossRef] [Google Scholar]

[7] Bastida Garcia J. L., González-Ronquillo M., Domínguez Vara I. A., Romero-Bernal J., Castelán Ortega O. (2011). Effect of field pea (*Pisum sativum* L.) level on intake, digestion, ruminal fermentation and *in vitro* gas production in sheep fed maintenance diets.Anim.Sci.J.82,654–662.10.1111/j.1740-0929.2011.00884.x

[8] Benti O. (2019). Comparing Yield Performance and Morpho-agronomic Characters of Landraces and Released Varieties of Field Pea (Pisum sativum L.) at Agarfa and Goro Woredas, Bale Zone, Oromia Region, Ethiopia. International Journal of Genetics and Genomics. D Vol. 7, No. 3, 2019, pp. 34-49. doi: 10.11648/j.ijgg.20190703.11

[9] Ben-Ze'Ev N., Zohary D. (1973). Species relationships in the genus *Pisum* L. Isr. J. Bot. 22, 73–91

[10] Benti O. and Yohannis P. 2017. "Genetic Variability and Association AmongAgronomic Characters in Selected Field Pea (*Pisum sativum* L.) Genotypes at Bale Zone, Sinana Research Center, Oromia Region, Ethiopia." *International Journal of Genetics and Genomics*, 5(6):63–75.

[11] Blixt, S. (1970). Pisum. In genetic resources in plants. Their exploration and conservation.O.H. Frankel and E. Bennet (eds). Inte. Biological Programme. Blackwell Scientific Publication, Oxford. PP.321-326.

[12] Bogdanova V. S., Kosterin O. E., Yadrikhinskiy A. K. (2014). Wild peas vary in their cross- compatibilitywith cultivated pea (*Pisum sativum* subsp. sativum L.) depending on alleles of a nuclear-cytoplasmic incompatibility locus. Theor. Appl. Genet. 127, 1163–1172. 10.1007/s00122-014-2288-9 [PubMed] [CrossRef] [Google Scholar]

[13] Burstin J., Alves-Carvalho S., Aluome C., Tayeh N., Brochot A. L., Carrère S., et al. (2014). Recent pea genomic resources will enhance complementary improvement strategies in this crop, in IFLRC VI and ICLGG VII Conference (Saskatoon, SK:). [Google Scholar]

[14] Brummer Y., Kaviani M., Tosh S. M. (2015). Structural and functional characteristics of dietary fibre in beans, lentils, peas and chickpeas. Food Res. Int. 67, 117–125. 10.1016/j.foodres.2014.11.009[CrossRef][Google Scholar]

[15] Burstin J., Gallardo K., Mir R. R., Varshney R. K., Duc G. (2011). Improving protein content and nutrition quality, in Biology and Breeding of Food Legumes, eds Pratap A., Kumar J. (Wallingford,CT:CAB International;), 314–328. 10.1079/9781845937669.0314

[16] Chahal, G.S., Gosal, S.S. (2002). Principles and procedures of plant breeding: biotechnological and conventional approaches. 978-81-7319-374-3

[17] Chandel, K.P.S., Joshi, B.S. (1983). Multivariate analysis in green-seeded pea Indian. J. Agric. Sci.53198200 Cousin, R. 1997. Peas (*Pisum sativum* L.). *Field Crops Research*, 53: 111-130.

[18] Cherinet Alem and Tazebachew Asres. (2015). Adaptability of field pea (*Pisum sativum* L.) varieties under irrigation, Western Amhara Region, Ethiopia. *International Journal of Plant Breeding and Genetics* 9 (1): 28-31.

[19] Clement S. L., McPhee K. E., Elberson L. R., Evans M. A. (2009). Pea weevil, *Bruchus pisorum*L. (Coleoptera: Bruchidae), resistance in *Pisum sativum* x *Pisum fulvum* interspecific crosses. Plant Breed. 128, 478–485. 10.1111/j.1439-0523.2008.01603.x

[20] CSA, (2019). Agricultural sample survey. Report on area and production of major crops, Volume I. Addis Ababa, Pp. 14

[21] Dahl W. J., Foster L. M., Tyler R. T. (2012). Review of the health benefits of peas (*Pisum sativum* L.). Br. J. Nutr. 108, S3–S10. 10.1017/s0007114512000852 [PubMed] [CrossRef] [Google Scholar]

[22] Daisy, E. k. (1979). *Food legumes: Crop and product digest*, 3rd eds., Tropical products institute, British, London .pp 295-314.

[23] Dawit Tadasse, Asfaw Telaye and Geletu Bejiga (1994). Genetic resource in Ethiopia, In: Asfaw Tlaye, Geletu Bejiga, Saxena, M.C. and Solh, M.B. (eds), Cool Season Food Legume of Ethiopia. Proceeding of the first national cool season legume review conference, 16-20 December 1993, Addis Ababa Ethiopia, ICARDA,Syria, pp. 79-96.

[24] Dotas V., Bampidis V. A., Sinapis E., Hatzipanagiotou A., Papanikolaou K. (2014). Effect of dietary field pea (*Pisum sativum* L.) supplementation on growth performance, and carcass and meat quality of broiler chickens. Livest. Sci. 164, 135–143. 10.1016/j.livsci.2014.03.024 [CrossRef] [Google Scholar]

[25] Davies D.R.(1976). Peas. In: Simmonds N.W. (ed.), Evolution of crop plants Longman, London, pp. 172–174.

[26] Duc G., Blancard S., Hénault C., Lecomte C., Petit M., Bernicot M.-H., et al. (2010). Potentiels etleviers pour développer la production et l'utilisation des protéagineux dans le cadred'uneagriculturedurable en Bourgogne. Innov. Agron. 11, 157–171. [Google Scholar]

[27] FAO. (1998). The State of World Genetic Resources for Food and Agriculture. FAO, Rome. Frankel, O.H.(eds). 1973. Survey of genetic resources in their centers of diversity. First Report. FAO/IBP, Rome.

[28] Fondevilla S., Almeida N. F., Satovic Z., Rubiales D., Vaz Patto M. C., Cubero J. I., et al. (2011). Identification of common genomic regions controlling resistance to *Mycosphaerella pinodes*, earliness and architectural traits in different pea genetic backgrounds. Euphytica 182, 43–52. 10.1007/s10681-011-0460-8 [CrossRef] [Google Scholar]

[29] Gemechu Keneni (2012). Genetic potential and limitations of Ethiopian chickpea (*Cicer arietinum* L.) germplasm for improving attributes of symbiotic nitrogen fixation, phosphorus uptake and use efficiency, and adzuki bean beetle (*Callosobruchus chinensis* L.) resistance. PhD Thesis, Addis Ababa University. Addis Ababa, Ethiopia.pp292.

[30] Gemechu Keneni, Fassil Assefa, Imtiaz M. and Endashaw Bekele, (2013). Genetic diversity for attributes of biological nitrogen fixation in Abyssinian field pea (Pisum sativum var.abyssinicum) germplasm accessions. *Ethiopian Journal of Applied Science and Technology*, 4(2): 1-21.

[31] Getachew, T. (2019). Pulse crops production opportunities, challenges and its value chain in Ethiopia: A review article. *Journal of Environment and Earth Science*, 9, 1. doi:10.7176/JEES

[32] Haddis Yirga and Dargie Tsegay. (2013). Characterization of dekoko (Pisum sativum var. abyssinicum) accessions by qualitative traits in the highlands of Southern Tigray, Ethiopia. African Journal of Plant Science, 7(10): pp. 482–487.

[33] Hagedorn, D.J. (1991). Handbook of Pea Diseases. Report No. A1167. Madison, WI: University of Wisconsin-Extension.

[34] Hayer F., Bonnin E., Carrouee B., Gaillard G., Nemecek T., Schneider A., et al. (2010). Designing sustainable crop rotations using Life Cycle assessment of crop combinations, in 9th European IFSA Symposium (Vienna:). [Google Scholar]

[35] Jha A. B., Arganosa G., Tar'An B., Diederichsen A., Warkentin T. D. (2013). Characterization of 169 diverse pea germplasm accessions for agronomic performance, Mycosphaerella blight resistance and nutritional profile. Genet. Resour. Crop Evol. 60, 747–761. 10.1007/s10722-012-9871-1 [CrossRef] [Google Scholar]

[36] Johnson, H.W., Robinson, H.P. and Comstock, R.E.(1955a). Estimate of genotypic and environmental variability in soybean. *Agronomy Journal*, 47:314-318.

[37] Kedir Yimam . (2020). Diversity Analysis and Identification of Promising Powdery Mildew Resistance Genotypes in Field Pea (*Pisum sativum*L.). *American Journal of Biological and Environmental Statistics*. Vol. 6, No.1, pp.7-16.

[38] Laudadio V., Nahashon S. N., Tufarelli V. (2012). Growth performance and carcass characteristics of guinea fowl broilers fed micronized-dehulled pea (*Pisum sativum* L.) as a substitute for soybean meal. Poult. Sci. 91, 2988–2996. 10.3382/ps.2012-02473 [PubMed] [CrossRef] [Google Scholar]

[39] Legesse, (2015). “Genetic Variability and Association of Characters for Yield and Yield Components in Some Field Pea (Pisum Sativum L.) Genotypes Grown in the Central Highlands of Ethiopia.” MSc Thesis, Haramaya University, Haramaya, Ethiopia.

[40] Marles M. A. S., Warkentin T. D., Bett K.E. (2013). Genotypic abundance of carotenoids and polyphenolics in the hull of field pea (*Pisum sativum* L.). J. Sci. Food Agric. 93, 463–470. 10.1002/jsfa.5782 [PubMed] [CrossRef] [Google Scholar]

[41] Martin-Sanz, A; Caminero, C; jing, R; Flavell, A.J. and Perez, M. (2011). Genetic diversity among Spanish pea (*Pisum sativum* L.) landraces, pea cultivars and the world *Pisum* spp core collection assessed by retro-transposon based insertion polymorphisms (RBIPS). *Spanish Journal of Agricultural Research* 9(1): 166-178.

[42] McPhee, K. (2003). Dry pea production and breeding, a mini-review. *Food Agricultural Environment* (1): 64-69.

[43] Messiaen, C.M., Seif, A.A., Mussa Jarso, and Gemechu Keneni. (2006). Pisum sativum L. In: Brink, M. and Belay, G. (Editors). PROTA 1: Cereals and pulses/Céréales ET légumes secs. [CD-Rom]. PROTA, Wageningen, Netherlands.

[44] Mitchell D. C., Lawrence F. R., Hartman T. J., Curran J. M. (2009). Consumption of dry beans, peas, and lentils could improve diet quality in the US population. J. Am. Diet. Assoc. 109, 909–913. 10.1016/j.jada.2009.02.029

[45] Mulusew Fikere, Tadele Tadesse, Setegn Gebeyehu and Bekele Hundie. (2010). Agronomic performances, disease reaction and yield stability of field pea (*Pisum sativum* L.) Genotypes in Bale Highlands, Ethiopia. *Australian Journal of CropScience*4(4):238-246.

[46] Macwilliam S., Wismer M., Kulshreshtha S. (2014). Life cycle and economic assessment of WesternCanadian pulse systems: the inclusion of pulses in crop rotations. Agric. Syst. 123, 43–53. 10.1016/j.agsy.2013.08.009 [CrossRef] [Google Scholar]

[47] MOA and NR, (2016). Plant Variety Release, Protection and Seed Quality Control Directorate, Crop Variety Register Issue No. 19. Addis Ababa, Ethiopia

[48] Mussa Jarso, Dereje G, Gemechu Keneni (2009). Procedures of Field Pea Improvement through Hybridization. Technical Manual No. 22, Ethiopian Institute of Agricultural Research. p 12.

[49] Nisar M, Ghafoor A, Khan MR, Qureshi AS (2006). Screening of Pisum sativum L. germplasmagainstErysiphe pisi. Botany 48 (2): 33-37.

[50] Nisar, M.A., Ghafoor, H., Ahmad, M.R., Khan, A.S., Qureshi, H. and Islam, M. (2008). Evaluation of genetic diversity of pea germplasm through phenotypic trait analysis. *Pakistan Journal of of Botechnology*, 40(5):2081-2086.

[51] Nemecek T., Von Richthofen J.-S., Dubois G., Casta P., Charles R., Pahl H. (2008). Environmentalimpactsof introducing grain legumes into European crop rotations. Eur. J. Agron. 28, 380–393. 10.1016/j.eja.2007.11.004 [CrossRef] [Google Scholar]

[52] Nemecek T., Kägi T. (2007). Life Cycle Inventories of Swiss and European agricultural production systems, in Final Report Ecoinvent V2. 0 No 15a. Agroscope Reckenholz-TänikonResearchStationART. Zurich; Dübendorf, CH: Swiss Centre for Life Cycle Inventories. SimaPro Ph.D., 7. [Google Scholar]

[53] Ochatt S. J., Benabdelmouna A., Marget P., Aubert G., Moussy F., Pontecaille C., et al. (2004). Overcoming hybridization barriers between pea and some of its wild relatives. Euphytica137, 353–359. 10.1023/B:EUPH.0000040476.57938.81 [CrossRef] [Google Scholar]

[54] Petr, S., Aubert, G., Burstin, J., Coyne, C.J., Ellis, N.T.H., Flavell, A.J., Ford, R., Hýb, M., Macas, J., Neumann, P., McPhee, K.E., Redden, R.J., Rubiales, D., Weller, J.L. and Warkentin, T.D. (2012). Pea (*Pisum sativum* L.) in the Genomic Era. Rev. Agron. 2:74115, ISSN 2073-4395.

[55] Reddy P.S. (1988). Genetics, Breeding and Varieties. In: Reddy P.S.(eds.),Groundnut. Publication and Information Division, Indian Council of Agricultural Research Krishi Anusandhan Bhavan, PusaNew Delhipp. 200–317.

[56] Russell, G.E. (1978). Plant breeding for pest and diseases resistance. Butterworth's London

[57] Santalla, M., Amurrio, J.M. and de Ron, A.M. (2001). Food and Food potential breeding value of green, dry and vegetal pea germplasm. *Canadian Journal of Plant Science*, 81:601-610.

[58] Seid Ahmed Kemal. (2015). *Phenomics in crop plants: phenotypic methods of fungal*

[59] Sharma, B. (1995). The role of plant breeding in increasing production of pulses in tropic and sub tropics. In: Sharama, B *et al*. [eds.], *Genetic Research and Education*: Current Trends and Next Fifty Years, 916–924. Indian Society of Genetics and Plant Breeding, New Delhi, India.

[60] Singh, B.D. (1990). Plant breeding: principles and methods Kalyani Publishers New Delhi

[61] Smýkal P, Kenicer G, Flavell AJ et al. (2011). Phylogeny, phylogeography and genetic diversity of the Pisum genus. Plant Genet Resour; 9: 4–18.

[62] Smýkal P., Jovanović Ž., Stanisavljević N., Zlatković B., Ćupina B., Đorđević V., et al. (2014). A comparative study of ancient DNA isolated from charred pea (*Pisum sativum* L.) seeds from an Early Iron Age settlement in southeast Serbia: inference for pea domestication. Genet. Resour. Crop Evol. 61, 1533–1544. 10.1007/s10722-014-0128-z [CrossRef] [Google Scholar]

[63] Srivastava, Saurabh, Roopa Lavanya, and G. M. Lal. (2017). "Genetic Variability and Character Association for Seed Yield in Chickpea (Cicer Arietinum L .)." *Journal of Pharmacognosy and Phytochemistry*, 6(4):748–50.

[64] Stein H. H., Everts A. K. R., Sweeter K. K., Peters D. N., Maddock R. J., Wulf D. M., et al. . (2006). The influence of dietary field peas (*Pisum sativum* L.) on pig performance, carcass quality, and the palatability of pork. J. Anim. Sci. 84, 3110–3117. 10.2527/jas.2005-744 [PubMed] [CrossRef] [Google Scholar]

[65] Sultana, Z., Islam, A.K.M., Hasan Mitu, M.K. and Mian, M.A.K. (2002). Genetic variability and character association in garden pea (Pisum sativum L. spp. hortense) Genotypes. Department of Genetics and Plant Breeding Bangabandhu sheikh Mujibur Rahman Agricultural University Gazipur 1706, Bangladesh.

[66] Tadele Tadesse and Edosa Fikru .(2009). Registration of Urjii, Field Pea Variety for Bale Highlands, Ethiopia. *East African journal of sciences* 3 (1):111-112.

[67] Tamene T., Gemechu K., Tadesse S., Musa J. and Yeneneh B. (2013). G x E interaction and performance stability for grain yield in field pea *(Pisum sativum* L.) genotypes. *International Journal of Plant Breeding*, 7(2): 116-123.

[68] Teshome E, and Tegegn A (2017). Comparative Study of Powdery Mildew (Erysiphe polygoni) Disease Severity and Its Effect on Yield and Yield Components of Field Pea (Pisum sativum L.) in the Southeastern Oromia, Ethiopia. Journal of Plant Pathology and Microbiology, 8: 410. doi: 10.4172/2157-7471.1000410.

[69] Teshome Legese. (2011). Genetic gain in grain yield and yield related traits of field pea(*Pisum sativum* L.) In Ethiopia. An MSc Thesis. Haramaya University. Haramaya, Ethiopia. Pp. 87.

[70] Thulin, M. (1989). Papilionoideae. In: Flora of Ethiopia, Pittosporaceae to Araliaceae. 3. (Hedberg, I. and Sue Edwards, S., eds.). 3:97-252. The National Herbarium, Addis Ababa, Ethiopia and Uppsala University, Sweden.

[71] Van der Maesen LJG, Kaiser WJ, Marx GA, Worede M. (1988). Genetic basis for pulse crop improvement: collection, preservation and genetic variation in relation to needed traits. In: Summerfield RJ (ed). *World Crops: Cool Season Food Legumes.* Kluwer Academic Publishers: Boston, MA, USA, pp. 55-66.

[72] Wallace, D.H., Yan, W. (1998). Plant breeding and whole-system crop physiology: Improving crop maturity, adaptation and yield University Press Cambridge UK.

[73] Wang T. L., Domoney C., Hedley C. L., Casey R., Grusak M. A. (2003). Can we improve the nutritional quality of legume seeds? Plant Physiol. 131, 886–891. 10.1104/pp.102.017665 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

[74] Warkentin TD, Smýkal P, Coyne CJ et al. Pea. In: De Ron AM (ed). Handbook of Plant Breeding: Grain Legumes. Springer-Verlag: New York, NY, USA, (2015), pp. 37-83.

[75] Willcox G., Buxo R., Herveux L. (2009). Late Pleistocene and early Holocene climate and thebeginningsof cultivation in northern Syria. Holocene 19, 151–158. 10.1177/0959683608098961 [CrossRef] [Google Scholar]

[76] Weiss E., Zohary D. (2011). The Neolithic Southwest Asian founder crops their biology and archaeobotany.Curr. Anthropol. 52, S237–S254. 10.1086/658367 [CrossRef] [Google Scholar]

[77] Westphal, E. (1974). *Pulses in Ethiopia, their taxonomy and agricultural significance*. Centre for agricultural publishing and documentation, Wageningen. pp. 176-193.

[78] Zohary D. (1999). Monophyletic vs. polyphyletic origin of the crops on which agriculture was founded in the Near East. Genet. Resour. Crop Evol. 46, 133–142. 10.1023/A:1008692912820 [CrossRef] [Google Scholar]