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Research Article

Seed Quality Analysis of Field Pea (*Pisum Sativum L.*) from Formal and Informal Sources in Enarj Enawuga and Yilmana Densa Districts, West Amhara Region, Ethiopia

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Abstract

The production and productivity of field pea crop in Amhara region depends mainly on the un availability of quality seed supply system for a number of improved varieties. Therefore, this study was conducted to assess the quality and seed management practices of field pea seeds from the informal and formal seed systems in Enarj Enawuga and Yilmana Densa Districts during 2016/17 cropping season. Seed samples of two field pea varieties were collected from both formal and informal sectors and tested for quality in Complete Randomized Design (CRD) with four replications. The quality of seed samples had significant difference for physical purity, germination and vigor indices among seed samples. Except for other crop seeds, all the seed samples from informal seed sector maintained the physical /analytical/ purity of seed quality components (above the standards). Most of the seed samples except four samples (seed samples collected from farmer two and twelve of Enarj Enawuga districts who grow Tegegnech variety (F2 and F12), farmer 18 and 22 of Yilmana Densa districts who grow Tegegnech variety (F18 and F22) had registered germination capacity above the standards (75%). The speed of germination was better to predict field emergence of the seed lot than the standard germination. Seedborne fungi such as Ascochyta pinodes, Ascochyta pisi, Fusarium sp, Phoma sp, Septoria pisi, Colletotrichum sp were found associated with the field pea seed. Among those fungi Ascochyta pinodes was the dominant. Most farmer seed management practices enable to maintain and improve their field pea seed quality in both districts. Extension should play a crucial role in training farmers in on-farm quality seeds of the field pea crop production and is therefore a prerequisite for the improvement of the informal seed system in both districts.

Introduction

Field pea is a cool season legume that is grown on 7,881,943 ha with production of 12.5 million tons worldwide. Ethiopia ranked first in Africa and sixth in the world in field pea production with an area of 0.23 million ha and 0.34 million tons [1]. Field pea is an important source of food and feed in developing and developed countries, respectively. Field pea is the major food legume with a valuable and cheap source of protein having essential amino acids (23-25%) that have high nutritional values for resource poor households [2]. The crop has important ecological and economic advantage in the highlands of Ethiopia, as it plays a significant role in soil fertility restoration being used as a break crop to minimize the negative impacts of cereal based mono-cropping [3]. It is also used as a source of income for the farmers and foriegn currency

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for the country [4]. In Ethiopia, the pulse crops showed a slow growth in productivity for the last ten years. The average yield of field pea was 1.461 t ha^{-1} in 2015/16 cropping season [5] and it was one of the crop where more work is expected to enhance its productivity [6].

According to [5], the Amhara Regional State produced 1,150,035.6 tons (35.57% of the country) on 86,792.1 ha and it was the second major producing region of field pea in Ethiopia next to Oromia Regional state. However, the average yield of the crop was 1.325 t ha-1, which was less than the national average yield of field pea. Enarj Enawuga and Yilmana Densa are potential districts for field pea production in Amhara Regional state but the productivity of field pea is declining. T**he total area and production of field pea were decreased by 40% and 25.9% respectively from 2008/09 to 2016/17** [7,8]. The limited used of new technologies of field pea production as one of the low productivity in the region and districts mentioned.

Seed is a crucial input for agricultural production and the most affordable external input for farmers (Kumar, et al. 2014). Seed availability and accessibility by farmers are determined by many factors including the crop breeding systems, institutional/organizational arrangements and socio-economic conditions of farmers [9]. It is noteworthy that an effective seed system is relevant to increased productivity and overall agricultural production [10].

The formal and the informal systems are in place in Ethiopia. There is also a system that combines the two referred to as an integrated seed system [11]. Formal Seed System Characterized by a clear chain of activities. It usually starts with plant breeding and promotes materials for formal variety release and maintenance. Regulations exist in this system to maintain variety identity and purity as well as to guarantee physical, physiological and sanitary quality. Seed marketing takes place through officially recognized seed outlets, and by way of national agricultural research systems and even through relief seed programs. The major actors of the formal system in Ethiopia are the Federal and Regional National Agricultural Research Systems (NARS), Ministry of Agriculture and Natural Resources (MoANR), Federal (Ethiopian Seed Enterprise (ESE), and Regional Seed Enterprises (Oromia-OSE, Amhara-ASE, Southern-SSE, Somali-SoSE) and private seed companies [11].

Informal seed systems are about the knowledge, skills and practices of seed selection, production, and exchange by farmers. Farmers obtain seed and varieties through informal networks based on exchange (bartering) or gifts from relatives, neighbors, and other farmers or cash purchases from other farmers or local markets [9].

A number of improved varieties of field pea are released by the federal and regional agricultural research institutes but still the quality seed supply is negligible and unable to satisfy the seed demand of end users. Moreover, there is little information on field pea seed quality and local knowledge in seed selection, maintenance and management practices. Therefore, baseline information on the current field pea seed quality used for production is important to identify the field pea quality seed supply problem and suggest the establishment/strengthening of field pea seed system. The objectives of this study were to asses: the quality and seed management practices of field pea seeds from informal and formal seed systems in Enarj Enawuga and Yilmana Densa Districts.

Materials and methods

Description of the study area

The field pea seed system study was carried out in Enarj Enawuga district in East Gojjam Zone and Yimana Densa district in West Gojjam Zone of Amhara Regional States (Figure 1).

Enarj Enawuga has an altitude ranges from 1100 to 3200 masl where 30%, 50% and 20% of the total land area lies in *Dega*, *Weynadega* and *Kolla*, respectively. The area receives a mean annual rainfall of 1228 mm with a mean maximum temperature of 25 ^{o}C and a mean minimum temperature of 22 ^{o}C. From the total area of 96,095 hectares about 45,053 hectares (46%) is cultivated land and the major crops grown in the district are *teff*, wheat, barely, maize, faba bean, grass pea, field pea and potato. The Enarj Enawuga district consists of 25 rural and three urban (towns) kebele administrations with 165,415 farm households and a total population of 185,124; and over 98% of the population is involved in agriculture [7].

Yilmana Densa district has an altitude in the range between 1552 to 3535 masl, and average annual rainfall of 1270 mm with the main rainy season from May to October. The district is classified into three traditional agro climatic zones of which 24%, 57% and 19% of the total area lies in *Dega, Weynadega* and *Kolla,* respectively. The Yilmana Densa district consists of 33 rural kebele administrations with a total human population of 217,356. The total area is 99,180 hectares, and about 54,508 hectares (55%) is covered with annual crops. The mixed crop and livestock farming is predominant, since the area is suitable for both rearing of livestock and cultivating crop. The majority of the farmers depend on growing *teff*, maize, wheat, barley, faba bean, field pea, haricot bean, and chickpea as major source of cash income and household consumption [8].

Formal field survey

The study involved both multi stage purposive and random sampling techniques to select sample farmers. The two study zones, two districts and six Kebele Administrations (KAs) were selected purposively for being a major field pea growing areas. First, two major field pea growing districts (Enarj Enawuga and Yilmana Densa) were selected where some interventions have been made in the dissemination of improved field pea production technologies. Second, three KAs with highest field pea growing areas from each district were selected in consultation with the experts from the Agricultural Offices of the respective districts. Third, a total of 200 sample farmers, of which 120 from Enarj Enawuga and the remaining 80 from Yilmana Densa district were randomly selected for the survey.

The questionnaire was designed and pre-tested in randomly selected farm households before the beginning

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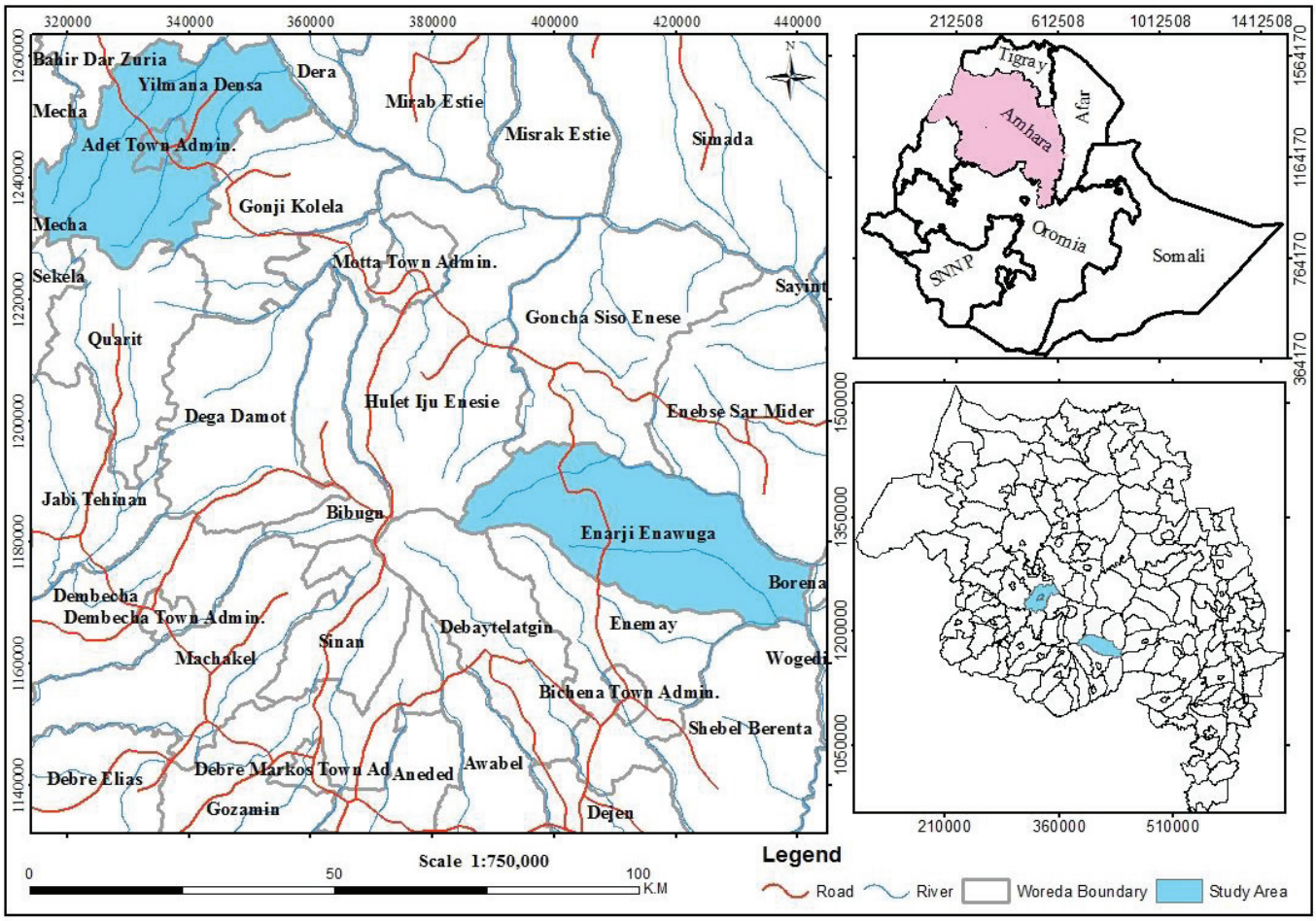

Figure 1: Location map of Enarj Enawuga and Yimana Densa Districts in Amhara Regional State Ethiopia.

of the survey and a checklist was prepared for the survey. During the survey, data was collected with the help of trained enumerators. Enumerators were trained on seed management practices, capacity to innovate performed by a seed system to avail high quality seed of varieties preferred by farmers. Group discussions with key informants were also employed in order to acquire supplementary information.

Secondary data collection

Secondary data was obtained from various sources such as reports, agricultural research centers, Central Statistical Agency (CSA), Amhara Seed Enterprise (ASE), Amhara Bureau of Agriculture (BoA), district agricultural offices, pervious findings, internet and other published and unpublished materials.

Seed quality analysis

Seed samples of two improved field pea varieties, Tegegech and Hassabe, which are grown by most farmers, were selected and seed samples were collected for laboratory seed quality test. In each KA, two seed samples from each field pea variety were collected from farmers i.e. 4 seed samples per KA. In total 12 seed samples each of two varieties (total 24 seed samples) were collected during the survey. In addition, one sample of Tegegnech from ASE and one of Hassabe from Adet Agricultural Research Center representing the formal seed source was included making a total of 26 seed samples to carry out laboratory seed quality and seedling emergence tests.

A sample of 1 kg seed was drawn from the farmers' seed harvested in 2016/17 cropping season for laboratory seed quality analysis including physical purity, thousand seed weight germination, vigor and seed-health tests. All tests were conducted according to ISTA rules [12] at Bahir Dar Seed Testing Laboratory and Bahir Dar Plant Health Clinic (for seed health). Field emergence tests were conducted at the green house of Amhara Regional Agricultural Research Institute, Bahir Dar.

Moisture content

For moisture test about 5g seed sample were taken and distributed on the surface of the container incubating in an oven at a constant high temperature of 130 °C ±1 and dried for about 1 hour with coarse grinding [12]. After drying, the sample were covered and allowed to cool for 30 minutes in desiccators and weighed again. The moisture content was calculated using the formula given below.

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$$M = \frac{M2 - M3}{M2 - M1} \text{ x100}$$

Where:

M1=the weight in grams of empty container and its cover

M2=the weight in grams of the container its cover and its content before drying and

M3= the weight in grams of the container and contents after drying

Physical purity

According to [12], the weight of submitted and working sample of field pea is 1000 g and 900 g, respectively. For each seed sample about 900 g seed sample was used for purity analysis. Each seed sample was divided into four replicates and separated in to three components: (i) pure seed, (ii) other crop seed and (iii) inert matter [12]. The components were weighed on precision balance to the nearest two decimal places and the percentages of each component were calculated as follows:

$$\text{Pysical purity (\%)} = \frac{\text{Weight of pure seed(g)}}{\text{Total weight of working sample(g)}} \text{ x100}$$

Thousand Seed Weight (TSW): Thousand seed weight was determined by counting from pure seed fraction and weighing eight replicates of 100 seeds and there mean weight has taken and multiplied by 10 [12].

Standard germination (StG) test

Standard seed germination test was carried for all seed samples in a completely randomized design (CRD). Four hundred seeds from the pure seeds component were taken and divided into four replicates of 100 seeds each and planted in sand media at a temperature of 20 °C. The first count were done 5 days after planting, and the final count 8 days after planting as specified by [12]. The result of the germination test was calculated as the average of four replicates. It was expressed as the percentage of normal seedlings. The percentages of abnormal seedlings, hard, fresh and dead seed were calculated in the same way.

$$\text{Germination}(\%) = \frac{\text{Total number of normal seedings}}{\text{Total number of seeds planted}} \text{x100}$$

Seed vigor test

Speed of germination: Hundred seeds were counted and taken from each source. The seeds were divided into four replicates of 25 seed each then after seeds were planted in between germination paper at 20 °C for 10 days in a dark room. The speed of germination (SG) was calculated according to [13].

The number of germinated seeds was counted every day from the first day of seed germination and the cumulative index was made by the formula:

$$N = \frac{n1}{1} + \frac{n2}{2} + \ldots + nx / x$$

Where:

*n*1.....*nx* is the number of speed seed germinated on day 1 to day *x*

1.....*x* is the number of days

Seedling dry weight: The seedling dry weights were measured after the final count of the Standard Germination (StG) test. Ten randomly selected seedlings excluding cotyledon from each replicate were taken, and placed in envelopes and dried in an oven at 80 °c for 24 hours then the dried seedlings were weighed to the nearest milligram (three decimal) using sensitive balance and the average seedling dry weight was calculated [14].

Seedlings shoot and root length: Assessment of the seedling shoot and root were taken after the final count in the standard germination test. After 8th day of sowing, ten normal seedlings were randomly taken from each replicate. The shoot lengths were measured from the point of attachment to the cotyledon to the tip of the seedling. Similarly, the root lengths were measured from the point of attachment of the cotyledon to the tip of the root. The average shoot and root lengths were computed by dividing the total shoot or root lengths by the total number of normal seedlings measured [15].

Vigor index-I and Vigor index-II: For each sample, vigor indices were calculated. Seedling vigor index-I was calculated by multiplying the standard germination with the average sum of shoot and root length after the final days of germination:

Vigor index I = Germination % × [Root length + Shoot length (cm)] [15].

Vigor Index II= (Seedling dry weight X Germination (%))/ 100 [16].

Field emergence index

Pot experiments were conducted for field emergence index using well mixed soil. Twenty five seeds of four replications were planted from each seed source using complete randomized design (CRD). The number of seedlings emerged out of sown seed were counted till no more seedlings were emerged. The field emergence index was determined by following formula [13].

$$EI = \frac{\text{Number of seedlings emerged}}{\text{Days of first count}} + \ldots + \frac{\text{Number of seedlings emerged at final count}}{\text{Days of final count}}$$

Field emergence (%): the total seedling emerged from the soil was summed up at the end of field emergence index experiment and it was calculated as field emergence in percent.

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$$\text{Field emergence}(\%) = \frac{\text{Total number of emerged seedlings}}{\text{Total number of seeds planted}} x100$$

Seed health testing

Agar plate was used which is the most common method used for identification of seed borne fungi [17]. One hundred (100) undamaged seeds per sample were surface sterilized quickly by rinsing in 70% ethanol alcohol followed by soaking in 1% NaOCl for two minutes and then washing by distilled water. The seeds then plated on general purpose agar medium (five seeds per plate) and were incubated for two weeks. Petri dishes were incubated at 28±1°c with 12 hours alternating cycles of day and darkness and fruiting bodies of pathogens were examined under compound microscope [18]. During the period the fungi were identified and recorded and the percentage seed infection were calculated. At the end of the incubation period, fungi growing out from seeds on the medium are examined under compound microscope and fungi identified. Identification is based on colony characters and morphology; fruiting structures, size, shape, color and septations (cross walls) of the conidiophores and conidia (spores) and compare these characteristics with reference culture or descriptions in identification manuals. Identification of fungi and appropriate reference materials were used and finally the occurrence of each fungal pathogen was recorded. According to [19], the frequency and percent of infection were determined by the following formulae given below.

$$\text{Frequency of infection} = \frac{\text{Number of samples with infection}}{\text{Number of samples collected}} x100$$

$$\text{Percent of infection} = \frac{\text{No. of infected seeds}}{\text{Total number of seeds examined}} x100$$

Data analysis

Information collected from the field survey was coded, tabulated and analyzed by using Statistical Package of Social Science (SPSS) version 23. Simple descriptive statistics was used to separate the mean, percentage and standard deviation to describe the socio-economic characteristics of the respondents.

Data collected data from laboratory and pot experiments were subjected to analysis of variance for Completely Randomized (CRD) using SAS (9.0). Treatment means were separated using Least Significance Difference (LSD) test. Pearson's correlation coefficient was used for correlating the data from seed quality and the field emergence index.

Results and discussion

Farmers seed management

Farmers field pea seed management practices such as seed selection, seed cleaning, seed storage and protection practices in both Enarje Enawuga and and Yilmana Densa districts were discussed.

Seed selection

Farmers used different selecting criteria and method to select their seed at different stages. Response from most informants revealed that farmers' selection criteria and practice were focused on observable attributes such as seed size and yield performance during harvesting, threshing and after threshing. Most of the selection practices were selected grain and very few based their selection on plants or pod. This indicates that farmers are interested in different traits of a variety.

Farmers select seed during harvesting and threshing (51.5%), just after threshing (37%) or just before planting (11.5%). Men (56.5%), women (21.5%), both men and women (7.5%) or all household members (14.5%) were responsible for selection as shown in Table 1. However female farmers are important in Enarj Enawuga (28%) as male in Yilmana Densa (58%). Some farmers selected; collected; threshed and stored seed separately for sowing and evaluated the crop the next season.

Table 1: Farmers seed selection and time of field pea seeds in Enarj Enawuga and Yilmana Densa districts (n=200).

Seed selection	Enarj Enawuga		Yilmana Densa		Total	
	n	%	N	%	n	%
Time of selection						
During harvesting and threshing	62	51.7	41	51.2	103	51.5
Just after threshing	49	40.8	25	31.2	74	37
Just before Planting	9	7.5	14	17.5	23	11.5
Responsibility of seed selection						
Female farmer only	34	28.4	9	11.2	43	21.5
Male farmer only	66	55	47	58.7	113	56.5
Both male and female farmers	7	5.8	8	10	15	7.5
All household members	13	10.8	16	20	29	14.5

Source: Own survey data, 2016/17 cropping season

Most farmers select seed before and/or after harvesting the crop. Some farmers designate part of the field and use the harvest as a seed. Field and plant selections are based on a set of criteria, which vary from place to place, crop to crop and farmer to farmer [20]. Similarly [21], also found that among farmers practicing selection, 53% selected plants before harvest in the field, 15% at harvest just before threshing, and 7% just after threshing while 18% just before sowing of common bean in southern Ethiopia [22]. Reported that women played a significant and key role in on-farm seed management in Nepal.

Seed cleaning

The majority (62.5%) of the respondents' clean by winnowing just before planting using homemade equipment known was *Sefed*, and this activity separate seeds by using differences in size and weight between seed and impurities. 37.5% of them by hand picking of large particles such as large soil clods or other inert matters to improve seed quality/ remove inert matter, remove small/broken damaged seeds and

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to remove weeds and other crops. Main cleaning time is just before planting. Men do the winnowing after threshing and women clean the seed at planting time.

About 57.5 % of the respondent farmers clean their seed to remove small or broken/damaged seeds, 30% of them were to remove weeds and other crops, and 12.5% to increase quality by removing inert matter (Table 2).

For most crops, cleaning of seed follows similar principles as for food grains using local practices and may include winnowing to remove light particles like straw and dust; sieving to select the seed by shape and size and hand-picking to remove damaged, diseased or discolored seeds [23]. Also reported that about 52% and 17% of the farmers cleaned their seed by hand-winnowing or hand-sieving, respectively, at planting time using handmade tools to increase purity, reduce weed contamination or even remove insect damaged seed grains. According to [24] all seed infested by insects must be destroyed to effectively remove sources of future infestation or contamination.

Seed storage and protection

Majority of the farmers (81%) used sacks and stored the seed in the house and 19% stored in local structures such as *gota/gotera* especially in the highland areas (Table 3). The average quantity of seed stored was 30 kg with range from the 15kg to 50 kg for field pea. They re-used fertilizer sacks without plastic linings to protect the seed from moisture. A study in Kenya shows that farmers stored beans in their houses (98%) or used some raised platforms near their houses (2%) [25]. During storage, the majority of the respondents (64%) used chemicals (phostoxin or actellic 2%) for storage pest control and the remaining 36% did not take any control measures. Farmers who take no control measure especially in Yilmana Densa distric believe that as bruchides are inside the seed treating the seed does not control the storage pest. None of the respondents use cultural methods to protect the seed from storage pest assuming that cultural measures do not have immediate result.

Advantages for farmers in storing their own seed include cash outlays are reduced, seed is available on time and nearby, and knowledge of varieties and management requirements [26]. The location, storage structures and the material used to construct the structures play an important role in enhancing the shelf-life and viability of the stored grain/ seed [25,27] found that the majority (63%) of farmers surveyed relied on chemical insecticides (actellic dust or phostoxin) and lack knowledge of cultural practices to control pea weevil in North and North West Ethiopia.

Table 2: Farmers' seed cleaning practice and purpose in Enarj Enawuga and Yilmana Densa Districts (n=200).

Seed Cleaning	Enarj Enawuga		Yilmana Densa		Total	
	n	%	n	%	n	%
Method of cleaning						
Winnowing	73	60.8	52	65	125	62.5
Hand picking	47	39.2	28	35	75	37.5
Purpose of Cleaning						
Improve quality/ remove inert matter	17	14.1	8	10	25	12.5
Remove small/broken damaged seeds	66	55	49	61.2	115	57.5
Remove weeds and other crops	37	30.8	23	28.8	60	30

Source: own survey data, 2016/17 cropping season

Table 3: Farmers' seed storage and protection measures in Enarj Enawuga and Yilmana Densa districts (n=200).

Seed Storage	Enarj Enawuga		Yilmana Densa		Total	
	n	%	n	%	n	%
Storage structure						
Sacks in the house	96	80	66	82.5	162	81
Gota/Gotera	24	20	14	17.5	38	19
Protection measures						
Chemicals	71	59.2	57	71.2	128	64
No measures taken	49	40.8	23	28.7	72	36

Source: own survey data, 2016/17 cropping season

Seed quality of field Pea

Field pea seed samples of two improved varieties, Tegegnech and Hassabe, were collected from informal (farmers) and formal (ASE and AARC) sources were analyzed for the main quality parameters moisture content, physical seed purity, thousand seed weight, physiological quality (germination and vigor) and seed health presented below.

Physical purity

There was highly significance difference in all physical purity parameters among seed samples collected from formal and informal seed source (Table 4). The physical purity ranged from 98.47% to 98.87% with a mean value of 98.66%. The highest physical purity was observed from sample F17 (98.87%) of Hassabe variety in Yilmana Densa followed by F12 of Hassabe variety from Enarj Enawuga district where as the lowest was from samples F19 (98.47%) and F15 (98.47%) of Tegegnech variety all from Yilmana Densa district informal seed source (Table 4). The highest contamination by other crop seeds was observed in seeds obtained from sample F23 (0.36%) of Tegegnech variety whereas the lowest was from sample F18 (0.31%) of Hassabe variety both from Yilmana Densa district informal seed source. On the other hand, contamination of field pea seed by inert mater was highest in seeds obtained from F19 (1.20%) and the lowest from F17 (0.77%) both of Hassabe variety from Yilmana Densa district informal seed source.

The mean separation showed no observed differences (except other crop seed) in physical purity and inert matter between formal and informal seed sources, varieties and districts (Table 4). Crop seed admixtures could occur at the time of sowing, harvesting (poor threshing floors) and post-harvest activities (threshing, seed cleaning or storage) that would result in increased percentage of other crop seed in the informal seed source of the study area. Crop seed admixtures could occur at the time of sowing, harvesting (poor threshing floors) and post-harvest activities (threshing, seed cleaning or storage) that would result in increased percentage of other crop seed in the informal seed source of the study area. The

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Table 4: Mean values of Physical Quality, Moisture Content, and Thousand Seed Weight of Field pea seeds from formal and informal seed sources.

Seed Samples	Pure seed	Other crop	Inert mater	Moisture	Thousand seed weight
F1	98.7475^{abcde}	0.3300^{def}	0.9000^{bcde}	13.7000^{abcde}	197.0450^{a}
F2	98.7875^{abcd}	0.3575^{abc}	0.8550^{cde}	13.7250^{abcd}	164.5300^{e}
F3	98.6575^{abcde}	0.3625^{abc}	0.9800^{abcde}	13.7000^{abcde}	194.9850^{ab}
F4	98.8425^{ab}	0.3200^{def}	0.8375^{cde}	13.6500^{bcdef}	148.0150^{fgh}
F5	98.6675^{abcde}	0.3500^{abcd}	0.9825^{abcde}	13.6500^{bcdef}	195.6650^{ab}
F6	98.5850^{abcde}	0.3500^{abcd}	1.0650^{abcde}	13.5250^{cdef}	152.3350^{f}
F7	98.4825^{de}	0.3450^{abcdef}	1.1725^{ab}	13.8500^{ab}	194.7350^{ab}
F8	98.6481^{abcde}	0.3443^{abcdef}	1.0075^{abcde}	13.8250^{abc}	144.4530^{h}
F9	98.7106^{abcde}	0.3418^{abcdef}	0.9475^{abcde}	13.6250^{bcdef}	175.7430^{d}
F10	98.6725^{abcde}	0.3425^{abcdef}	0.9850^{abcde}	13.6500^{bcdef}	144.3930^{h}
F11	98.5750^{abcde}	0.3325^{bcdef}	1.0925^{abcd}	13.6250^{bcdef}	188.1450^{c}
F12	98.8575^{ab}	0.3275^{cdef}	0.8150^{de}	13.7500^{abcd}	147.5100^{fgh}
F13	98.5150^{cde}	0.3525^{abcd}	1.1325^{abc}	13.6500^{bcdef}	193.0730^{abc}
F14	98.6550^{abcde}	0.3575^{abc}	0.9875^{abcde}	13.4000^{ef}	143.7200^{h}
F15	98.4775^{e}	0.3475^{abcde}	1.1750^{ab}	13.6250^{bcdef}	189.5780^{bc}
F16	98.8006^{abc}	0.3593^{abc}	0.8400^{cde}	13.3750^{f}	145.0330^{h}
F17	98.8750^{a}	0.3475^{abcde}	0.7775^{e}	13.6000^{bcdef}	194.7480^{ab}
F18	98.5525^{bcde}	0.3125^{f}	1.1325^{abc}	13.5500^{bcdef}	145.5200^{gh}
F19	98.4775^{e}	0.3150^{ef}	1.2075^{a}	13.5250^{cdef}	193.0730^{abc}
F20	98.6781^{abcde}	0.3443^{abcdef}	0.9775^{abcde}	14.0000^{a}	148.4500^{fgh}
F21	98.5575^{bcde}	0.3375^{abcdef}	1.0725^{abcde}	13.5750^{bcdef}	193.1630^{abc}
F22	98.6925^{abcde}	0.3575^{abc}	0.9500^{abcde}	13.4500^{def}	152.7930^{f}
F23	98.5525^{bcde}	0.3675^{a}	1.0750^{abcde}	13.6250^{bcdef}	192.3450^{abc}
F24	98.8075^{abc}	0.3425^{abcdef}	0.8500^{cde}	13.7000^{abcde}	144.0450^{h}
ASE	98.7031^{abcde}	0.3218^{def}	0.9750^{abcde}	13.7250^{abcd}	197.9660^{a}
AARC	98.6500^{abcde}	0.3325^{bcdef}	1.0175^{abcde}	13.7250^{abcd}	151.5650^{fg}
Mean	98.66	0.34	0.99	13.64	170.81
LSD (5%)	0.080	0.009	0.084	0.090	6.100
CV%	0.22	7.55	22.50	1.80	13.50
Formal	98.67	0.32	0.99	13.72	174.76
Informal	98.66	0.34	0.99	13.63	170.16
Tegegnech	98.62	0.34	1.03	13.66	192.78
Hassabe	98.70	0.34	0.95	13.64	148.85
Enarj E.	98.68	0.33	0.97	13.66	171.79
Yilmana D.	98.64	0.34	1.00	13.62	169.84

LSD (5%) values with the same letter in a column are not significantly different at $p \geq 0.05$. F1-F12=seed sample from farmer Enarj Enawuga, All odd numbers =Tegegnech, All even numbers= Hassabe, ASE=seed sample Tegegnech variety from Amhara Seed Enterprise, AARC=seed sample Hassabe variety from Adet Agricultural Research Center. F13-F24=seed sample from Yilmana Densa district

result is in agreement with the reports of [28] and [29] who found no significant differences in physical purity and inert matter between seed sources except for other crop seed in *teff* and barley crops, respectively.

According to the national field pea certified seed standard [30], the percentage of pure seed, inert matter and other crop seeds should be 97%, 0.2% and 1%, respectively. Except for other crop seeds, all the seed samples maintained the physical purity above the certification standards. Similarly [31] reported that most of the samples collected from farmers satisfied the physical purity standards set for wheat seed production in Ethiopia.

Thousand seed weight

Highly significant differences in thousand seed weight were observed among treatments. The average thousand seed weight of the entire seed sample collected was 170.81g ranging from the lowest of F14 (143.72 g) and F16 (145.03 g) of Hassabe variety from Yilmana Densa district to the highest from ASE (197.966 g) from formal seed sector and F1 (197.04 g) of Tegegnech variety from Enarj Enawuga of informal

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seed source. Tegegnech variety showed higher thousand seed weight than Hassabe variety could be due to differences in seed size (Table 4).

Thousand grain weights is one of important traits of seed quality. It depends to embryo size and seed storage for germination and emergence [29,31,32]. Found significant difference in thousand seed weight in barley and wheat varieties, respectively.

Physiological seed quality

Standard germination: The overall average mean germination percentage was 84.27% with the range from 72.75% to 95.5%. The highest value was recorded for Tegegnech variety from seed sample F23 (95.5%) in Yilmana Densa district informal seed source and Amhara Seed Enterprise (94.5%) formal seed source. Seed samples of Tegegnech variety obtained from F19 (94.5%), F17 (92.75%), F13 (92.25%) from Yilmana Densa and F7 (92%) from Enarj Enawuga districts informal seed source showed better normal seedling percentage. Seed samples of Hassabe variety obtained from F12 (72.75%) in Enarj Enawuga district of the informal seed source showed lowest normal seedling percentage. The lowest abnormal seedlings were observed from seed samples F21 (0.00%) in Yilmana Densa and F11 (0.00%) Enarj Enawuga districts. It is followed by F23 (1.00%) all of Tegegnech variety from Yilmana Densa district informal seed source and Amhara Seed Enterprise (1.00%) of formal seed source. The highest abnormal seedlings were observed from F12 (12.00%) followed by F2 (8.00%), F4 (8.25%) from Enarj Enawuga and F18 (7.75%), F22 (8.25%) from Yilmana Densa districs. All of which were from Hassabe variety of informal seed source. The dead seedlings showed lower from seed samples F13 (3.00%), F19 (2.5%) and F23 (3.5%) of Tegegnech variety from Yilmana Densa district informal seed source while the highest were from F18 (18.75%) of Hassabe variety from Yilmana Densa district informal seed source (Table 5).

Most of the seed samples except four (samples 2 and 12 of Hassabe variety in Enarj Enawuga while 18 and 22 of Hasssabe variety from Yilmana Densa districts) from the informal seed sources had registered germination capacity above certified seed of EQSA (75%) (Table 5).

The mean separation showed observed difference in normal and abnormal seedlings between the seed sources and varieties but no observed difference in normal and abnormal seedlings and dead seeds between the districts. The dead seeds only showed difference between varieties (Table 5). The difference in production management, timely harvest and post-harvest activities are all important factors that would affect germination. Tegegnech variety has larger seed size with higher germination and vigor than Hassabe with lower seed size. Large seed size having more food storages and utilized it at a faster rate to have greater rate of stem elongation and accumulation of root and shoot dry weight than small seed sizes. The result is in agreement with the studies of [33] in pea [29,31]. Also found that there were highly significant ($p < 0.001$) differences in germination between different seed sources of wheat and *teff* respectively.

Vigor tests

Highly significant differences of vigor indices were observed among treatments (Table 6). The difference genetic, environmental condition during seed development, seed size and density, mechanical damage, seed aging and deterioration observed between seed source, variety and location could affect vigor differences among treatments.

Speed of germination

The average speed of germination was 25.34 (Table 6). The highest speed of germination F5 (28.41) of Tegegnech variety from while the lowest were from F4 (22.58) of Hassabe variety both from Enarj Enawuga informal seed source. The mean separation test has showed speed of germination was the same for formal and informal seed sources for both locations. There exist differences in speed of germination related to variety. The result is in agreement with [29,34] for soybean and barely, respectively. Both found difference speed of germination only for variety.

Root and shoot length

The highest and lowest shoot length was F6 (13.85) of Hassabe variety and F9 (11.62) cm Tegegnech variety both from Enarj Enawuga informal seed source, respectively and the root length was range from Ase (15.8) of Tgegnech variety representing the formal seed source to F22 (9.77) cm of Hassabe variety from Yilmana Densa district informal seed source (Table 6). It is assumed that seedlings with well-developed shoot and root systems would withstand any adverse conditions and provide better seedling emergence [23].

The mean separation showed observed difference among vigor indices (except for shoot length) between formal and informal seed sources and varieties but not between districts (Table 6). This could be due to the difference in pre and post-harvest management between seed sources and seed size between two varieties examined [29]. Found significant difference between varieties and seed sources for vigor one and speed of germination whereas [28,31] found the difference only for root length and vigor index one between different seed sources. Previous research indicated that under less suitable weather conditions during seed development, seed vigor was affected to a larger extent by the cultivar than by the location [35].

Field emergence

The mean filed field emergence percentage of collected sample was 81.45% and it ranges from the highest ASE (88.75%) of Tegegnech variety to the lowest F10 (71.75%) of Hassabe variety from Enarj Enawuga district informal seed source. The seed samples F4 (84.75%), F6 (85.00%) from Enarj Enawuga and F18 (85.00%) from Yilmana Densa district of Hassabe variety as well as F5 (86.25%) from Enarj Enawuga and F23 (86.75%) from Yilama Densa district of Tegegnech variety informal seed source also showed higher field emergence percentage.

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Table 5: Mean value of Standard germination of samples collected from formal and informal seed source.

Seed Samples	Standard Germination	Abnormal Seedlings	Dead Seedlings
F1	90.50 ^{abc}	2.00^{gh}	7.50^{hijk}
F2	74.25^{ij}	8.00^{b}	17.75^{ab}
F3	88.25^{bcde}	2.00^{gh}	9.75^{efghi}
F4	80.75^{fgh}	8.25^{b}	11.00^{defgh}
F5	88.50^{bcd}	2.50^{fgh}	9.00^{fghij}
F6	76.75^{hij}	7.00^{bc}	16.25^{abcd}
F7	92.00^{ab}	3.75^{ef}	4.25^{jk}
F8	79.25^{ghi}	6.75^{bc}	14.00^{abcdef}
F9	84.75^{def}	6.00^{cd}	9.25^{efghij}
F10	77.75^{hij}	6.75^{bc}	15.5^{abcd}
F11	85.50^{cdef}	0.00^{i}	14.50^{abcde}
F12	72.75^{j}	12.00^{a}	15.25^{abcd}
F13	92.25^{ab}	4.75^{de}	3.00^{k}
F14	76.75^{hij}	7.50^{bc}	15.75^{abcd}
F15	83.75^{defg}	3.25^{efg}	13.00^{bcdefg}
F16	76.50^{hij}	6.00^{cd}	17.50^{ab}
F17	92.75^{ab}	2.00^{gh}	5.25^{ijk}
F18	73.50^{j}	7.75^{b}	18.75^{a}
F19	94.25^{a}	3.25^{efg}	2.50^{k}
F20	80.50^{fgh}	6.75^{bc}	12.75^{bcdefgh}
F21	92.25^{ab}	0.00^{i}	7.75^{ghijk}
F22	74.75^{ij}	8.25^{b}	17.00^{abc}
F23	95.50^{a}	1.00^{hi}	3.50^{k}
F24	80.50^{fgh}	6.00^{cd}	13.50^{abcdef}
ASE	94.50^{a}	1.00^{hi}	4.5^{ijk}
AARC	83.25^{efg}	4.75^{de}	12.00^{cdefgh}
Mean	84.27	4.75	0.99
LSD (5%)	3.03	1.19	2.29
CV%	9.60	67.00	22.50
Formal	88.8	2.8	8.2
Informal	83.5	5.0	11.4
Tegegnech	90.6	2.3	7.0
Hassabe	77.8	7.1	14.9
Enarj E.	83.5	5.0	11.4
Yilmana D.	85.0	4.4	10.5

LSD (5%) values with the same letter in a column are not significantly different at $p \geq 0.05$. F1-F12 = seed sample from farmer Enarj Enawuga, All odd numbers = Tegegnech, All even numbers = Hassabe, ASE = seed sample Tegegnech variety from Amhara Seed Enterprise, AARC=seed sample Hassabe variety from Adet Agricultural Research Center. F13-F24 = seed sample from Yilmana Densa district

The time and rate of seedling emergence are affected by an array of interacting factors including genetic constitution, seed dormancy, seed vigor, depth of planting, soil impedance and aeration, temperature and water supply [36,37].

Although many seeds germinate satisfactorily under ideal laboratory conditions, they may fail to emerge successfully in the field [38,39]. Simple correlation between germination and vigor tests with field emergence were done (Table 7). Standard germination showed an intermediate and non-significant correlation (r=0.25) with field emergence. The result showed that the standard germination test was not a good indicator for field emergence [40]. had also found no significant correlation between the standard seed germination and the field emergence [28]. However found that a positive and highly significant correlation between germination and seedling emergence of *teff* seed.

Speed of germination is the only vigor test that showed intermediate significant correlation (r=0.47) with field emergence. The speed of germination was better to predict field emergence of the seed lot than the standard germination.

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Table 6: Mean values of Vigor parameters of field pea collected samples from formal and informal seed source

Sample	SG	RL	SL	DW	VI	VII	EI	EP
F1	27.02^{abcd}	12.47^{efg}	12.09^{bcd}	1.08^{hij}	2219.90^{def}	0.977^{ghijklm}	3.06^{abcd}	84.00^{bcd}
F2	22.88^{gh}	13.10^{cdef}	12.93^{abcd}	1.18^{ghi}	1936.20^{ghijkl}	0.88^{jklmn}	2.81^{gh}	80.5^{cdef}
F3	27.77^{abc}	14.17^{abcde}	13.57^{ab}	1.27^{defghi}	2445.40^{bc}	1.12^{fghij}	2.91^{defg}	79.50^{ef}
F4	22.58^{h}	14.00^{bcde}	12.22^{abcd}	1.33^{cdefgh}	2117.70^{efg}	1.08^{fghijk}	3.03^{bcd}	84.75^{ab}
F5	28.41^{a}	14.20^{abcde}	12.62^{abcd}	1.34^{cdefgh}	2372.00^{bcd}	1.18^{defgh}	3.17^{abc}	86.25^{ab}
F6	25.86^{abcdefg}	10.52^{hi}	13.85^{a}	1.04^{ij}	1867.60^{jklm}	0.80^{lmn}	3.00^{cdef}	85.00^{ab}
F7	24.24^{defgh}	14.00^{bcde}	12.75^{abcd}	1.87^{b}	2461.30^{b}	1.72^{b}	2.80^{gh}	77.00^{fg}
F8	22.94^{fgh}	11.00^{ghi}	13.03^{abcd}	1.08^{hij}	1871.90^{ijklm}	0.859^{klmn}	3.03^{bcde}	83.50^{bcde}
F9	26.17^{abcdefg}	13.05^{def}	11.62^{d}	1.13^{hij}	2090.20^{efghi}	0.959^{hijklm}	2.88^{defg}	80.00^{edf}
F10	23.75^{defgh}	13.66^{bcde}	13.02^{abcd}	1.28^{defghi}	2074.20^{efghij}	1.00^{ghikjlm}	2.61^{i}	71.75^{h}
F11	26.87^{abcd}	14.23^{abcd}	11.75^{cd}	1.61^{bc}	2224.10^{cde}	1.37^{cde}	3.04^{abcd}	84.5^{abc}
F12	22.46^{h}	13.10^{cdef}	12.87^{abcd}	1.30^{defghi}	1890.20^{hijklm}	0.94^{hijklm}	2.81^{gh}	77.25^{fg}
F13	26.36^{abcdef}	11.52^{fgh}	12.60^{abcd}	1.17^{ghij}	2227.10^{cde}	1.08^{ghijk}	2.91^{defg}	80.00^{def}
Sample	SG	RL	SL	DW	VI	VII	EI	EP
F14	23.10^{efgh}	13.57^{bcde}	11.67^{d}	1.20^{fghi}	1926.90^{ghijkl}	0.92^{ijklmn}	2.67^{hi}	74.25^{gh}
F15	24.60^{cdefgh}	13.03^{def}	12.10^{abcd}	1.24^{efghi}	2105.00^{efgh}	1.04^{ghijkl}	2.85^{efgh}	78.25^{fg}
F16	23.89^{defgh}	10.52^{hi}	11.92^{bcd}	1.07^{hij}	1715.00^{lm}	0.82^{lmn}	2.88^{defg}	80.00^{def}
F17	24.21^{defgh}	13.67^{bcde}	13.02^{abcd}	1.42^{cdefg}	2473.70^{b}	1.31^{cdef}	2.88^{defg}	80.00^{def}
F18	26.48^{abcde}	11.19^{ghi}	13.35^{abcd}	1.04^{ij}	1802.40^{klm}	0.76^{mn}	3.17^{abc}	85.00^{ab}
F19	26.55^{abcde}	14.92^{ab}	12.09^{bcd}	1.53^{cd}	2544.20^{b}	1.44^{c}	2.83^{fgh}	77.75^{fg}
F20	24.67^{cdefgh}	11.37^{fghi}	11.72^{d}	1.05^{ij}	1866.00^{jklm}	0.94^{klmn}	2.89^{defg}	79.50^{ef}
F21	25.10^{abcdefgh}	13.10^{cdef}	12.27^{abcd}	1.27^{defghi}	2360.20^{bcd}	1.16^{efghi}	2.89^{defg}	80.50^{cdef}
F22	27.02^{abcd}	9.77^{i}	12.60^{abcd}	0.90^{j}	1669.90^{m}	0.67^{n}	2.89^{defg}	79.50^{ef}
F23	26.73^{abcd}	14.82^{abc}	11.97^{bcd}	1.48^{cde}	2561.70^{ab}	1.42^{dc}	3.20^{ab}	86.75^{ab}
F24	24.94^{bcdefgh}	13.02^{def}	11.90^{bcd}	1.25^{efghi}	2002.00^{fghijk}	1.00^{ghijklm}	2.89^{defg}	79.50^{ef}
ASE	28.18^{ab}	15.80^{a}	13.48^{abc}	2.22^{a}	2768.30^{a}	2.09^{a}	3.22^{a}	88.75^{a}
AARC	24.32^{cdefgh}	13.73^{bcde}	12.68^{abcd}	1.46^{cdef}	2201.10^{efd}	1.21^{cdefg}	3.04^{abcd}	84.12^{bcd}
Mean	25.34	13.11	12.56	1.34	2170.12	114.50	81.45	2.95
LSD (5%)	1.07	0.71	0.47	0.13	125.22	14.69	1.85	0.07
CV%	11.3	14.50	10.12	27.16	15.40	34.20	6	6.65
Formal	26.25	14.76	13.08	1.84	2484.69	1.66	86.43	3.13
Informal	25.19	12.84	12.47	1.25	2117.69	1.05	80.62	2.92
Tegegnech	26.45	13.93	12.59	1.49	2401.52	1.35	82.28	2.99
Hassabe	24.23	12.30	12.52	1.19	1938.70	0.93	80.62	2.91
Enarj E.	25.39	13.04	12.72	1.38	2185.74	1.17	82.10	2.97
Yilmana D	25.29	12.83	12.40	1.29	2154.50	1.11	80.8	2.93

LSD (5%) values with the same letter in a column are not significantly different at p ≥ 0.05. SPG=Speed of germination; SL=Shoot length; RL=Root length; V1=Vigour index 1; VII =Vigour index 2; DW=Seedling dry weight; EI=Emergence Index; EP= Emergence Percentag. LSD values with the same letter in a column are not significantly different at p ≥ 0.05. F1-F12=seed sample from farmer Enarj Enawuga, All odd numbers =Tegegnech, All even numbers= Hassabe, ASE=seed sample Tegegnech variety from Amhara Seed Enterprise, AARC=seed sample Hassabe variety from Adet Agricultural Research Center. F13-F24=seed sample from Yilmana Densa district

Speed of germination measures the rate at which the seeds germinate and where those seedlings with the higher index were expected to show rapid germination and seedling emergence and escape adverse field conditions. Speed of germination is an important measure of vigor. It depends on the time taken to reach 50% germination at constant temperature. Seeds with low vigor take longer time to germinate. Many researchers have examined speed of germination [13,38,39] had found a significant correlation with field seed emergence.

Seed health test

The seed health quality of field pea seed samples obtained from different sources was checked for the presence of seed-borne fungal pathogen. The fungi found associated with field pea seed were *Ascochyta pinodes*, *Phoma sp*, *Fusarium sp*, *Septoria pisi*, *Ascochyta pisi and Colletotrichum sp*. From the total field pea seed samples collected from informal and formal sources, 57.6% of the samples were infected with *Ascochyta pinodes*, 50% by *Phoma sp*, and 26.9% by *Fusarium sp*, 15.3% by *Septoria pisi*,

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7.7% by *Aschochyta pisi* and 7.6% by *Colletotrichum sp*. (Table 8). The result is in agreement with [41] who found that out of 94 field pea samples tested for seed health, 57.4% were infected with Ascochyta with infection levels as high as 23%.

Since the percentage of seed infection is higher than 0.2%, all the seed samples did not meet the national seed standard of maximum infection level for certified seed in Ethiopia [42]. found that pre-basic seed of Adi and Tegegnech varieties produced at HARC had infection levels of 4.0% and 3.0%, respectively which are higher than the seed health standards in Ethiopia.

Summary and conclusion

Field pea can play an important role for household food security and sustainable farming systems. Availability of quality seed of improved field pea varieties at suffient quantity is one of the major constraints to increase productivity. This study was conducted to assess the seed quality of field pea seed grown in Enarj Enawuga and Yilmana Densa districts during the 2016/2017 cropping season.

Two varieties of field pea were collected from both formal and informal seed sources and were laid out in complete randomized design (CRD) with four replication in laboratory and seedling emergence tests in green house.

The existing seed system of field pea in both districts is dominated by the informal seed system and a very limited supply of seeds of field pea was available from limited activity of the formal seed system. Low efficiency of the current field pea formal system and due to poor support to strengthening the in formal seed system was one of the major reasons that most of the farmers in both districts to produce the crop from farm saved seeds of farmers' cultivars.

It is well known that the formal sector is more regulated from variety development to seed marketing and distribution components in the national seed system. The seed from the formal seed sector should pass through the application of formal seed certification process in the country. Well organized seed management practices in the formal seed sector contributes to the seed quality which results better production and productivity of field pea crop in both districts.

The seed quality and seed emergence test indicated the presence of observed difference among seed samples of two varieties (Tegegnech and Hassabe) obtained from formal and informal seed system in the two districts (Enarj Enawuga and Yilmana Densa). The seed samples collected from some farmers also exhibited in seed quality test results as equal to the seed samples from formal seed system with the same parameters. There are also samples even better than seed sample from formal for some quality parameters. This may be due to farmers seed management practices (seed selection, cleaning and separate storage) enabled them to keep varieties seed quality comparable with the national standard. Most farmers, who save seed, however select seed at harvesting, threshing, and/or planting time. Farmers stored seed separately from grain either in sacks or in *gotta/gottera*, and the majority of farmers cleaned seed before planting to improve seed quality. However none of the seed samples from different sources met the seed health standards of EQSA. It could be concluded that high quality field pea seed from the informal sector could be produced under farmers' condition by adopting better management practices. .

Some of the farmers in the study districts experienced some good practices to keep the field pea seed quality to the national standard for the crop. The seed management practice differs from farmers to farmers. This could be strengthened through

Table 7: Simple Pearson correlation coefficients between physiological quality and seedling emergence of field pea sample from formal and informal seed source

	SPG	RL	SL	DW	VI	VII	EP
Standard Germination	0.51**	0.51**	-0.09ns	0.59**	0.91**	0.76**	0.25ns
Speed of Germination	1	0.16ns	0.11ns	0.20ns	0.45*	0.32ns	0.47*
Root length		1	-0.06ns	0.79**	0.82**	0.78**	0.08ns
Shoot length			1	0.13ns	0.09ns	0.08ns	0.20ns
Seedling dry weight				1	0.79**	0.96**	0.22ns
Vigor Index I					1	0.88**	0.25ns
Vigor Index I						1	0.26ns
Emergence percentage							1

*,**significant at $p \leq 0.05$ and $p \leq 0.01$, respectively; SPG: Speed of germination; RL: Seedling Root Length; SL: Seedling Shoot Length; DW: Seedling Dry Weight; VI: Vigor Index 1; VII: Vigor Index 2; EP: Emergence Percentage

Table 8: The percent and frequency of infection by fungal species on field pea seed in Enarj Enawuga and Yilmana Densa districts.

Pathogens	Source		Variety		Location		No. of
	Informal	Formal	Tegegnech	Hassabe	Enarj Enawuga	Yilmana Densa	samples Infected (%)
Ascochyta pinodes	2.30	0.80	3.40	0.90	1	3.24	57.60
Phoma sp.	0.67	1	0.70	0.69	0.97	0.42	50
Fusarium sp.	0.82	0	0.77	0.74	0.38	1.12	26.90
Septoria pisi	0.29	0	0.32	0.22	0.43	0.11	15.3
Ascochyta pisi	0.35	0	0	0.64	0.38	0.60	7.70
Colletotrichum sp.	0.49	0	0.91	0	0.24	0.66	7.60

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good agricultural extension service to become as a source of quality seed supply.

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