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Research Article

Effect of Conventional and Improved Threshing Methods on Common Beans (*Phaseolus vulgaris* L.) Seed Quantity and Quality in Central Rift Valley of Ethiopia

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Abstract

Due to poor quality seeds currently, many seed lots of common beans (*Phaseolus vulgaris* L.) producing by various seeds producers in Central Rift Valley of Ethiopia were rejecting by external seed regulatory body. The field and lab experiments were carried out at MARC, TMSR farm field, and seed research and quality control lab, Ethiopia to investigate the effect of conventional and improved threshing methods on genotypes of common beans seed quantity and quality. The experiment consisted treatment combinations of threshing methods and genotypes and its interaction effects. Each variety was planted in the field using RCBD design with four replications. Seed quality parameters were carried out at seed research and quality control, and plant protection laboratories. At laboratories each seed sample was analyzed using CRD design with three replications. The result showed that there were high significant ($P < 0.01$) interaction effects between variety and threshing method for seed yields, damaged seeds, 1000-seed weight, standard germination, dead seeds, shoot and root lengths, and vigour index-I. Speed of germination was decreased significantly ($P < 0.01$) as days of emergence increased with the number of germinated seeds decreased slightly. This finding suggested that seed quantity losses reduced while seeds threshed by stick beating followed by portable multi crop thresher machine in small and medium scale production irrespective of varieties. Significant interaction effects of variety with threshing method and significant differences among varieties and threshing methods in laboratories might be reliable indicators for seed quantity and quality losses.

Keywords

Threshing Methods, Seed Losses, Germination, Speed of Germination, Vigour Induces

1. Introduction

Common bean (Phaseolus vulgaris L; 2n=22) is the world's most important food legume which is used for direct human consumption [1]. The common bean production is greater than 12 million tons annually in the world [2, 3]. Since it is high in nutrient content and commercial potential, common bean holds great promise for fighting hunger, increasing income and improving soil fertility in Sub Saharan Africa. The crop occupies more than 3.5 million hectares in sub-Saharan, but production is concentrated in the densely populated areas of East Africa, the lakes region and the highlands of southern

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Africa. It is the second most important crop next to cow pea in eastern, central, and southern Africa [4, 5]. These regions are the primary bean growing regions in Africa, with a combined production of almost 1 million metric tons [6]. The area covered by common bean production in Ethiopia was 98,508.53 ha and 240,841.81 ha for white and red common bean respectively with total area of 339,350.34 ha and total production of about 584,157.96 tons. The average white and red common bean productivity is 1.74 tons/ha and 1.71 tons/ha respectively. It is ranked the second important crop next to faba bean in terms of area coverage among pulse crops. Generally, pulses covered 13.75% of the grain crop area; where common bean, faba bean and chickpea accounted for 2.78%, 4.27% and 1.65% respectively. Common bean is mainly grown in Eastern, Southern, South Western and Central Rift Valley areas of Ethiopia [7]. Largely it is produced in Oromia region, SNNPR and Amhara region with their area coverage of 136,211.73 ha (40.14%), 97,666.65 ha (28.78%) and 74,288.9 (21.78%) ha respectively. The rest 9.19% is produced in other regions of Ethiopia [8].

Seed processing is a fundamental component in any planned seed production program, which aims at improving the seed characteristics [9]. The purpose of the threshing process is to detach the seeds from the panicles. The process is achieved through tractor treading, mechanical feeding, stick beating by hand, animal power trampling or using a combination of these approaches. Threshing methods (Tractor, cattle, stick beating and multi crop thresher) are the critical factor dictating the seed quality losses during the threshing operations. Mechanical threshing method i.e. multi crops thresher is a machine to separate seeds/ grains from the harvested crops and provide clean seed without much loss and damage. During threshing, seed loss in terms of broken seed, un-threshed seed, blown seed, spilled seed etc. should be minimum. Clean and un-damaged seeds fetches good price in the market as well as it has long storage life. Introduction of multi crop thresher reduced the drudgery of the operator and gave comparatively higher output per unit time. However, to be effective some thresher machines select seed sizes and seed moisture contents with optimum physiological maturity of the crops. Manual threshing methods i. e. trampling of animals team on the beans and beating beans with stick by man power at farm field on the mats or canvas surface are traditional methods followed by farmers depending upon capacity, seed lot size and situation. Threshing by bullock trampling is practiced on large scale production in our country but it is also time consuming and involves drudgery. Tractor treading in many places is now used in place of animals trampling. In all above methods the threshed materials are subjected to winnowing either in natural wind flow or blast from winnowing fan for separation of grain from straw [10].

Different threshing methods produce breaks, cracks, bruises and abrasions in seeds which in turn results in abnormal seedlings of questionable planting value. It is obvious that from the available information mechanical injury to seed not only reduces production of normal seedlings but also decreases the storage potential of damaged seed that apparently would have produced normal seedlings prior to storage. The noticeable manifestation of physical seed damage includes fractures of the radical or bruising of the cotyledons which are difficult to detect under the seed coat. In extreme instances damage to the radical can result in abnormal seedlings which fail to germinate. Any damage to the cotyledons is also concerns because it retards translocation of essential nutrients to growing embryonic axis which culminates in delayed seedling growth [10]. Loss of viability and vigour under different threshing method is a common phenomenon in many crop seeds but it is well marked in pulse crops which may cause internal damage and create subsequent germination and vigor problems [11].

Common beans have been grown for early generation seeds in Melkassa Agricultural Research Center for numerous years. Seed is the nucleus of farmer’s production activities hence its quality should be guaranteed at all times [12]. About 90% of all the food crops grown in the world are propagated by seeds. In any crop production systems, good quality seed inspires the confidence of farmers, because all other inputs will merely assist the seed to produce optimally. Despite good yields, there have been problems with rejection of seed lots because of poor seed quality [13]. Seed quality deterioration can be caused by both the physiological ageing of seed and mechanical damage. The mechanical damage is considered as common reason for poor seed quality in several medium and large seeded legumes. This occurs mainly when seeds are harvested and threshed by several threshing methods at 10-12% seed moisture contents (SMC). Seeds must be dry to the optimum moisture contents to complete development and reach high seed quality parameters that can survive the threshing methods without significant damage. Even though the crop has tremendous importance for the country’s economy; seed quality is highly challenged by different factors among which threshing method is common in the study area. Moreover, various varieties responded differently to all threshing methods for seeds quality parameters. Therefore, the objective of this study was to investigate the effects of threshing methods on seed quality and quantity of common bean genotypes.

2. Materials and Methods

2.1. Description of Experimental Site

The field experiment was conducted at the experimental and early generation seed multiplication farm fields of Melkessa Agricultural Research Center in 2022/2023 cropping season at Melkassa. Melkassa Agricultural Research Centre is located at 8°25'17" N and 39°19'56" E with the average altitude of 1550 m.a.s.l. in the Central Rift Valley of Ethiopia. Melkassa is characterized by high temperature throughout the year, particularly in May, combined with high sunshine hours, low humidity, and generally dry conditions except during very few wet months of July and August. It receives a mean annual rainfall of 763 mm with erratic distribution with peaks occurring in July and August in a mono-modal pattern. The annual average minimum and maximum temperatures at the Centre were 13.8 °C, and 28.6 °C, respectively. The soil type of the experimental site was a well-drained silt clay loam type, largely developed from the quaternary volcanic deposit parent materials.

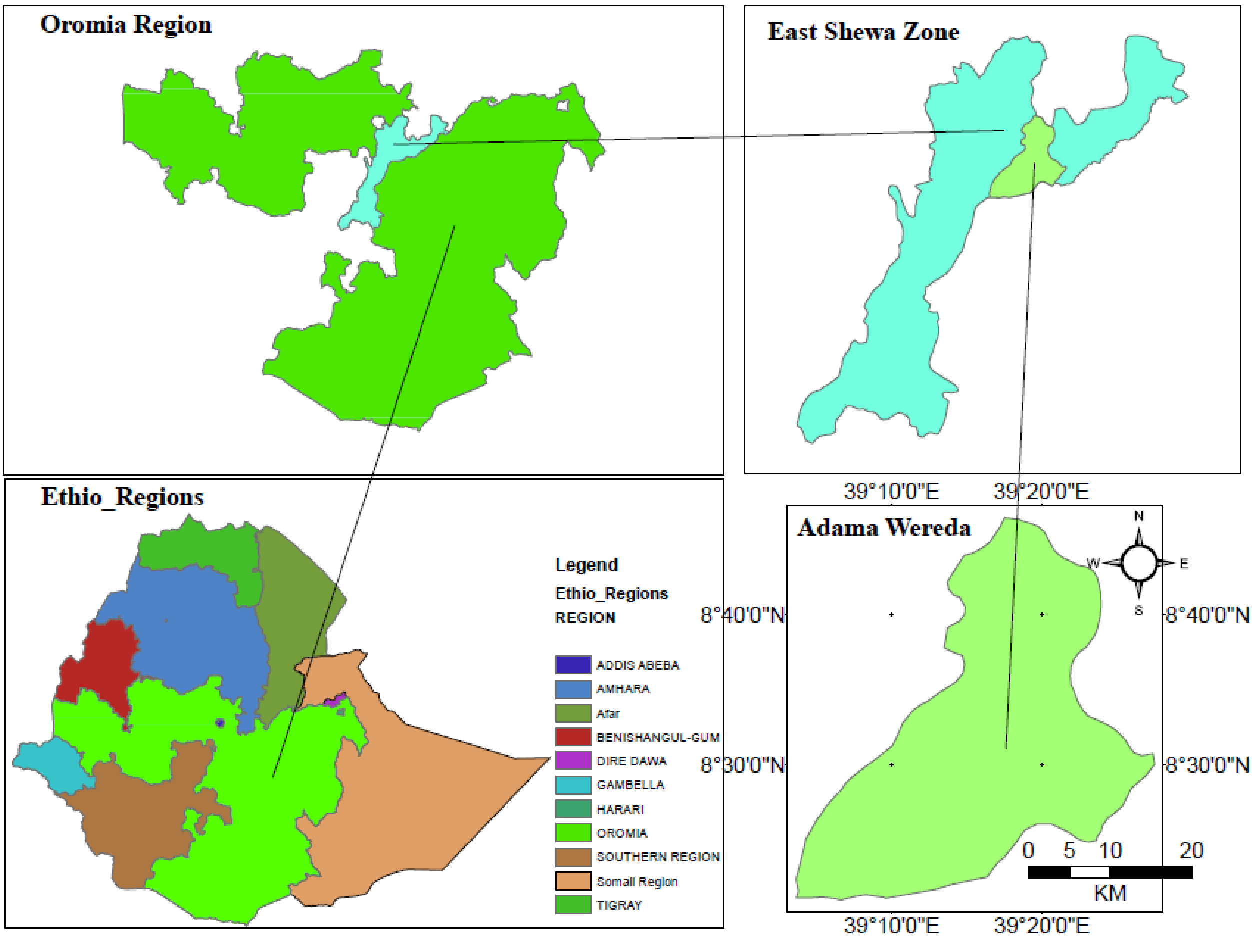

Figure 1. Map of study area.

2.2. Field Experiment: Procedures

Three popular common bean varieties (Awash-1 (A-1), Awash-2 (A-2) and Nasser) were selected and planted in the third week of June in 2022 at spacing of 40 cm between rows and 10 cm between plants. DAP fertilizer was applied during planting time of the crop. Crop management was carried out as described by [14]. After seeds have physiologically matured enough all varieties from each plot was uprooted separately by human daily laborers and heaped in small amount (locally called "nado") in the farm fields for two to three days to dry the seeds with pods before thresh. After two to three days of drying the heaped seeds with pods collected to the same place and ready for thresh at moisture content of 15-17%. Each plot was threshed separately by using four threshing methods (Figure 2). After three common beans genotypes have harvested and collected in one or more places threshing by tractor treading, stick beating, multi crops thresher and cattle trampling were carried out. Collected common bean seeds to one place were threshed by trampling under feet with a team of animals and beating it with a flail by group of daily laborers on layers of 30 to 60 cm thick on jean's canvas in the fields. After common beans have been threshed it was spread on canvas around warehouses till the moisture contents of seeds reduced to optimum (13%) [15].

Manual threshing is the most common practice in the developing countries, particularly in Ethiopia. Largely bullocks treading on have been practicing on large scale production for the past three decades based on the farmers' capacity, area coverage and other situations. These traditional threshing methods were time consuming and requested intensive daily laborers. Presently in many places threshing by tractor is becoming popular instead of animals for treading on by many farmers even through renting. Furthermore in the last five years in some areas of the country introduction and using of mechanical threshers started by MARC for common bean seed was a good new for small holder farmers. Mechanical thresher was established to reduce the number of daily laborers and increased the amount of threshed seeds in quintal per hour. In this study multi crop thresher was used to thresh all three varieties of common beans. After common bean seeds have threshed by four types of threshing methods they were subjected to winnowing in natural wind blow for separation of seeds from straw and others impurities. Conventional (Cattle trampling, stick beating and tractor treading) and improved (multi-crop thresher) threshing methods for seed quantity of selected common bean varieties were evaluated. Losses of common bean seeds were assessed. Damaged seeds were evaluated through visual observation of seed samples collected from each variety on testa damaged at top or bottom, broken/ cracked of cotyledons to half or less than half and shrinkled seeds. Also removal of all or half of seed cover was taken as damages. Seed damages might be caused due to the effect of threshing methods in addition to moisture contents, seed sizes, genetic characters and their interactions effects.

2.3. Experimental Design and Setup

The experiment at the field condition was laid-out as simple randomized complete block design (RCBD) with four replications. Seed rate of each common beans variety for each plot was 11 kg. In the field condition the treatment was three varieties planted by four replications. Each variety was planted on total area of 4400 m^2 by four replications. Individual plot size was 20 m wide by 55 m length. Each plot was harvested, threshed and cleaned separately. After all seeds have threshed, each common variety was cleaned manually by throwing the seeds with straw in open air blow using spade to separate seeds from straw & other inert matters on canvas in the fields as usual. After threshed seeds have blown and dried to the optimum moisture contents of the seeds i.e. 13% [15]. Before cleaning by machine and sorting by human laborers seed samples were collected from each container. Primary samples were mixed to be composite samples where they were mixed with soil seed divider and one kilogram of working sample was drawn and submitted to seed quality lab for seeds quality analysis. Experiment in the laboratory condition was laid out as completely randomized design (CRD) arranged by factorial with three replications. At the laboratory condition the treatments were three varieties and four threshing methods replicated three times. Inert matters, broken and physically damaged seeds were separated from pure seeds and weighed by sensitive balance in laboratory.

Figure 2. *Threshing methods for common bean seeds (A-D).*

2.4. Seed Quality Analysis

2.4.1. Laboratory Tests: Procedures

One kilogram of seed samples were taken from each common bean seeds threshed through four threshing methods. Each sample was mixed thoroughly and 700 g of working samples were taken and submitted to laboratory for quality tests. Pure seeds from each common bean variety of seed sample taken from working samples were subjected to laboratory for seed quality analysis. All seed quality tests were done in Seed technology and plant protection laboratories at Melkassa Agricultural Research Center following the International Seed Testing Association [16] procedures.

2.4.2. Experimental Setup and Design for Laboratory Conditions

Experiments done at laboratory were conducted using a completely randomized design (CRD) with a factorial arrangement of common bean varieties and threshing methods with three replications. Seed quality test parameters were done separately from pure seed samples obtained during physical purity analysis that submitted to laboratory as working sample.

2.4.3. Collected Data from Field and at Laboratory Conditions

Collected data in the field condition for quantity analysis of common bean seeds was evaluation of seed yields. Data collected in the laboratory for seed quality analysis were analytical purity, moisture contents, thousand seed weight, standard germination, speed of germination, seedling dry weight, average seedlings shoot and root lengths, seedling vigour index-I and seedling vigour index-II and seed healthy tests.

2.4.4. Physical Purity Test

From each common bean seeds threshed through four methods 1 kg of total samples wa submitted to laboratory for seeds quality analysis. Among the submitted samples, 0.7 kg of working sample of each common bean variety was subjected for seed quality tests whereas 0.3 kg of each variety was stored for re tests if any mistake or doubt occurred on the result of tested seed quality parameters. Each working sample was divided into two portions for physical purity analysis (350 g). The purity components were separated into pure seeds, inert matters and other crop seeds where each component was weighed using analytical balance. Finally, the percentage composition of the seed lot was calculated based on the weight of each component [16].

$$\text{Purity } (\%) = \frac{\text{Weight of pure seed}}{\text{Weight of total sample}} \times 100 \qquad (1)$$

2.4.5. Moisture Contents Determination

Direct seed moisture meter tester was used for seed moisture content determination. The moisture content as a percentage by weight was calculated to one decimal place following the standard formula [16].

$$\text{Moisture contents } (\%) = \frac{\text{M1+M2}}{2} \qquad (2)$$

Whereas, M1 and M2 are the readings of moisture replicates 1 and 2 from the moisture meter.

2.4.6. Thousand Seed Weight

Thousand seed weight of each sample was determined through counting eight replications of 100 seeds each was taken randomly from the pure seed fraction and weighed and then calculated the average weight of 1000 seeds. The numbers of seeds were taken in to by using electronic seed counter on 100 seeds of eight replicates. 1000-seed weight was measured (in g) using electronic balance from the produce of each variety and threshing method [16].

2.4.7. Physiological Seed Quality Test

The physiological seed quality test is the viability and vigor of seed which determines the germination and subsequent seedling emergence and crop establishment in the field as well as the storage potential of the seed lot.

2.4.8. Seed Germination Test

Germination test was done for all seed samples collected from each variety threshed through four threshing methods. The pure seed component, separated during purity analysis was considered for this test. Four hundred common bean seeds were divided into four replicates of one hundred seeds replication each and planted in sand substrata, and Complete Randomized Design (CRD) was used. The first count was made at the 5th days whereas final count was carried out at 9th days. The seed was planted at ambient room temperature for 9 days [17]. On the final day of germination test, seedlings were evaluated into normal seedlings, abnormal seedlings, dead seeds and infected seeds components. For each seed sample the result was expressed as mean percentage of normal seedlings. To calculate the percentage of normal seedlings, abnormal seedlings, dead seeds and infected seeds the following formula was used.

$$\text{Germination } (\%) = \frac{\text{Number of normal seedlings}}{\text{Total number of seed sown}} \times 100 \qquad (3)$$

2.4.9. Seed Vigour Tests

The germination test is routinely utilized to evaluate seed physiological potential in laboratories. However, it frequently produces results that overestimate seed performance under less favorable environmental conditions. The use of vigour tests has been useful to identify consistent differences in the performance of seed lots under a wide range of environmental conditions [18]. Seed vigour could be determined by different physiological test parameters that carried out at laboratory. The different measures of seeds vigour determinants are as follows:

(i). Speed of Germination

Seeds were planted from pure seeds after physical purity have done in pots at green house by four replications. 50 seeds were planted in each replication and kept at room temperature until eleven days where no further germination had taken place. Starting at fifth day of planting, each day normal seedlings were counted and recorded at each day until all seeds capable to produce normal seedlings had germinated. An index was calculated by dividing the number of seedlings counted each day for number of the days in which they were counted as follows [19].

$$\text{Speed of Germination (\%)} = \frac{\text{No.of normal seedlings} + \cdots + \text{No.of normal seedlings}}{\text{days of first count days of final count}} \quad (4)$$

(ii). Seedlings Shoot and Root Lengths

The seedlings shoot and root lengths were evaluated after the final count during seeds standard germination test. Ten normal seedlings were taken randomly from each replicate. Shoot length was measured from the point of attachment of the seed to the tip of the seedling. Similarly, the root length was measure from the point of attachment to the tip of the root. The length of normal seedlings was measured using ruler [17]. The average seedlings shoot and root lengths were computed by dividing the total shoot and or root lengths by the total number of normal seedlings measured [20].

(iii). Seedlings Dry Weight

The seedling dry weight was measured after the final count of standard germination test. Randomly 10 seedlings were selected from each replicate that uprooted and appropriately placed in envelopes and dried in an oven dry machine at 80 ± 1 ℃ for 24 hrs. The dried seedlings were weighed to the nearest two decimal places in gram and the average seedlings dry weights were calculated according to [20].

(iv). Vigour Indices

The seedling vigour indices were calculated for each sample as per [21] and expressed in number by using formula below: (1) Vigour index-I = Standard germination x (Average of seedlings shoots length + Average of seedlings roots length) and (2) Vigour index-II = Standard germination × Mean of seedlings.

Vigour index-I: Vigour index-I was calculated from each seed sample. Seedling vigour index-I was calculated by multiplying the germination percentage of normal seedlings with the sum of average seedlings shoot and root lengths after nine days of standard germination. Mathematically, the formula for vigour index-I is described as below:- Vigour index-I = Standard germination x (Average of seedlings shoots length + Average of seedlings roots length).

Vigour index-II: Vigour index-II was calculated from each seed sample. Vigour index-II was calculated by multiplying the normal germination percentage with mean of normal seedlings dry weight according to [17] mathematically, the formula for vigour index-II is described as below:- Vigour index-II = Standard germination × Mean of seedlings.

2.4.10. Seed Healthy Tests

Common bean seeds samples were taken from pure seeds after physical purity analyzed in seed research and quality control laboratory at MARC. Seed samples taken from pure seed were taken to plant pathology laboratory for seed healthy test at Melkassa Agricultural Research Center (MARC). Identification of pathogens were conducted by taking thirteen (30) seeds from each samples and surface sterilize by submerging first in 3% chlorox solution for 5 min and then in 70% ethanol for 3 min followed by rinsing with distilled water for 5 minute. Finally the rinsed seeds with distilled water were dried on sterilized filter paper in laminar flow cabinet. PDA and Nutrient Agar Medias were used to identify fungal and bacterial diseases respectively. From one sample fifty seeds were placed on PDA media and the other fifty seeds were placed on Nutrient Agar Medias. Five seeds were placed on each plate by three replications. Plates were incubated at room temperature for 6-8 days in the dark room/ isolation room. Disease incidence was recorded by dividing the number of seeds showing bacteria and/or fungi sign to the total number of tested or cultured seeds [16].

2.5. Data Analysis for Field and Laboratory Experiments

The Statistics 8 software was used in the analysis of variances (ANOVA). Mean separation was carried out using honestly significance differences (HSD) at 5% level of significance. Simple randomized complete block design (RCBD) by four replications was used at the field. The mean percentage of seed yields was computed and used for comparison of threshing methods and varieties using HSD at 5% level of significance. Completely randomized design (CRD) with factorial arrangements by three replications was used in laboratory. The mean percentage of seed quality parameters were computed and used for comparison of threshing methods, varieties and their interaction effects.

3. Results and Discussions

Common beans seed yields: Among the wide range of common bean types grown in Ethiopia, the most commercial varieties are pure red and pure white colored beans and these are becoming the most commonly grown types with increasing market demand [22]. The results indicated that there was high significant variation exhibited at ($p<0.01$) among varieties regarding seed yields. The mean yields of common bean seeds obtained from A-1, A-2 & Nasser varieties were 16.24 qt./ ha, 18.39 qt./ ha & 20.87 qt./ ha respectively (Figure 3). There were high significant ($p<0.01$) interaction effects of variety with threshing method regarding seed yields. Even though the same agronomic practices have been made to all varieties, the obtained seeds yield differences might be due to genetic potential of the varieties and environmental factors as well. Among the environmental factors that affect seed yields was delay of harvesting time that cause large amount of seed losses which occur before or during the harvesting operations at field conditions. The findings of this study are in agreement with study conducted by [23, 24] that revealed there were significant variations in seed yield for different crops including common bean.

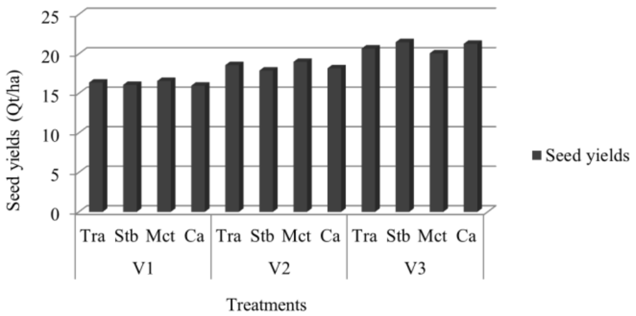

Figure 3. *Means of seed yields (Qt/ ha) through 'varieties*threshing methods' interaction effects.*

Evaluation of common bean seed quantity loss/ damaged: The results indicated that Awash-1 variety threshed by cattle treading showed high significant (P<0.01) interaction effect for seed damage/ yield loss. Awash-2 variety showed higher seed damage/ yield loss when threshed by tractor treading and cattle trampling and appearances to have caused the significant 'varieties*threshing methods' interaction effect. Results suggested that both Awash-1 and Awash-2 varieties may require other threshing methods to minimize the percentage of seed damage/ yield loss. Means of damaged seeds higher when threshed by cattle trampling (18 Kg/ha) followed by tractor treading (15.89 Kg/ha). The lowest seed damaged was recorded in seeds threshed by stick beating (13.89 Kg/ha) followed by multi crop thresher (14.22 Kg/ha) (Figure 4). Threshing by stick beating was using for seeds produced in small plot areas and excessive daily laborers available whereas multi crop thresher was using for larger areas producing for researches and early generation seed multiplication. Damaged parts of seeds could be on testa damaged at top or bottom, broken/ cracked of cotyledons to half or less than half, removal of all or half of seed coat and shrinkled seeds. Seed damages might be caused due to threshing methods in addition to other factors like moisture contents, seed sizes, genetic characters and their interaction effects.

Generally, seeds threshed by manual and tractor treading showed higher damage than seeds threshed by mechanical thresher irrespective of varieties. Even though mechanical threshing was done to enhance seed quality and reduce seed quantity loss, multi crop thresher exposed some seeds to damages which reduces seed quality due to internal and external damages occurred during threshing. This process must be controlled to minimize seed damage during commercial seed production. Clean and undamaged seed raises good price in the market as well as it has long storage life. Similarly, Shah [25] reported that grain spillage, incomplete separation of the grains from chaff, grain breakage due to excessive striking are some of the major reasons for losses during the threshing process. Ponmani [26] conducted the experiment to evaluate the various threshing methods for barnyard millet, such as manual beating with pliable stick, threshing with tractor treading, threshing using paddy thresher. Seed quality parameters *viz*., germination (77%), vigour index (1701) also maximum with the seeds threshed by paddy thresher.

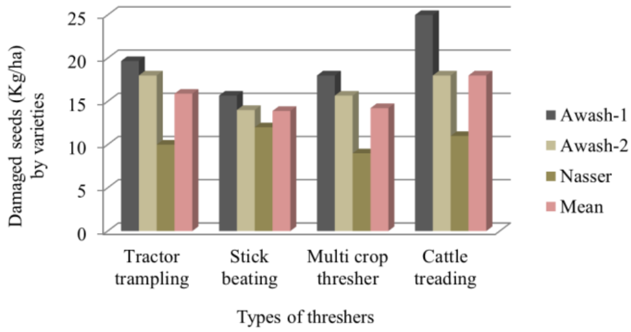

Figure 4. *Effects of 'varieties*threshing methods' means for quantity loss or damaged seeds in Kg/ ha.*

Physical purity analysis: Threshing by tractor trampling resulted in higher physical purity than others three threshing methods irrespective of the varieties. We found that cattle treading was higher seed purity than tractor trampling, stick beating by man power and multi crop thresher but the purity difference didn't showed significant variation regardless of the varieties. Differences among the varieties were significant at (P<0.05) for percentage of pure seeds whereas none significant difference showed among the threshing methods. The proportions of pure seed for the varieties threshed by various threshing methods were in the highest range of the purity standard of common bean seeds for EGS in Ethiopia except; Awash-1 variety threshed by tractor trampling, stick beating with human power and multi crop thresher. Among factors that affect common beans seed quality or physical purity were heavier threshers increased seeds cracking, bricks, other matters and structures. Thickness of common bean seeds that ready for threshing also major factor where low thickness exposed seeds for cracking and other challenges. However, Awash-1 variety threshed by cattle treading and Awash-2 and Nasser varieties threshed by four threshing methods fulfilled the national seed quality standard of common beans seed set for physical purity (Table 1). According to the national common bean seed quality standard, the minimum percentage of pure seed, maximum percentages of inert matter and other crop seeds should be 99%, 1% and 0%, respectively for seed classes of pre basic and basic seeds [15]. The inert matter for various crops is different which include seed units and all other matter and structures that not defined as pure seed or other seed [16]. Data in the bracket were transformed by square root transformation method [27]. Among purity components, there were no significant differences observed between varieties and threshing methods for other crops seeds.

Table 1. *Interaction effects of 'varieties*threshing methods' for PS, IM and OCS.*

Varieties	Threshing methods	Seed quality parameters		
		PS%	IM%	OCS%
Awash-1	Tra	98.00bc	2.00ab	0.00(0.71)a
	Stb	97.27c	2.73a	0.00(0.71)a
	Mct	98.00bc	2.00ab	0.00(0.71)a
	Ca	99.00ab	1.00bc	0.00(0.71)a
Awash-2	Tra	99.00ab	0.80bc	0.20(0.82)a
	Stb	99.00ab	1.00bc	0.00(0.71)a
	Mct	99.00ab	1.00bc	0.00(0.71)a
	Ca	99.00ab	1.00bc	0.00(0.71)a
Nasser	Tra	99.60a	0.40c	0.00(0.71)a
	Stb	99.00ab	0.67bc	0.33(0.88)a
	Mct	99.50a	0.50bc	0.00(0.71)a
	Ca	99.20ab	0.80bc	0.00(0.71)a
HSD (0.05)		1.42ns	1.53ns	0.59(0.18)ns
CV		0.48	44.41	446(14.21)
Grand means		98.80	1.16	0.04(0.53)

Tra= Tracter, Stb= Stick beating, Mct= Multi crop thresher, Ca= Cattle, PS= Pure seeds, IM= Inert matters, OCS= Other crops seeds. Means followed by the same letter within the same column are not significantly different at 5% level of probability, according to hsd test.

Thousand seed weight: Thousand seed weight were showed high significant interaction effect (P < 0.01) for varieties and threshing methods. The result of thousand seed weight between varieties across threshing methods indicated that there were significant variation for tractor trampling, stick beating, multi crop thresher and cattle treading. Moreover there were significant interaction effect between variety and threshing methods. Interaction effect of mean weight of thousand seed weight for varieties and threshing methods were significant which ranged from 138.10 to 182.33 g, 139.37 to 184.33 g and 173.67 g to 197.37 g for Awash-1, Awash-2 and Nasser respectively in the order of tractor treading, stick beating, multi crop thresher and cattle treading (Table 2). The variation might be due to genotypes, threshing methods and environmental factors. Internally damaged seeds which are not visible by naked eye that caused by threshing methods can affect 1000-seed weight of the crops. Similarly, Zewdie [28] reported that a thousand seed weight within the seed lot may vary due to different factors such as varietal differences, inter-plant competition for light, water, and nutrient and the effect of diseases that contribute to a wide range of seed size.

Moisture contents determination: Regarding moisture contents of common beans varieties, the result indicated that there was none significant interaction effects observed between variety and threshing method. However, there were significant (P<0.05) differences happened among varieties and high significant (P<0.01) difference observed among threshing methods. The average moisture contents for common bean varieties of Awash-1, Awash-2 and Nasser were 11.40, 11.94 and 11.65% respectively. However, the national seed quality standards set for moisture contents of common bean seeds used for early generation seed production was 13% [15]. Far below and above the optimum seed moisture contents affect the common bean seed quality. The means of moisture contents for three varieties established in the range of maximum percentage of seed moisture contents standard for common bean seeds in Ethiopia. Invisible damage in the internal part of seeds during several threshing methods and undamaged seeds has different moisture contents. The moisture contents of damaged seeds have might be lower moisture contents than pure seeds since attacked seeds simply expose and loss their moisture contents.

Determination of seeds germination: The result showed that there was significant (P<0.01) interaction effect between varieties and threshing methods regarding normal germination. Highly significant (P<0.01) differences obtained among the varieties whereas none significant differences observed between threshing methods. Each variety namely; Awash-1, Awash-2 and Nasser was threshed similarly through four threshing methods. Nasser variety showed the greatest germination loss (5.33%) when threshed by multi crop thresher and looks to have caused the significant 'variety*threshing method' interaction effect (Table 4). Awash-1 indicated that there was significant interaction effect on loss of germination percentage (8% & 5.34%) when threshed by cattle trampling and multi crop thresher respectively. Awash-2 showed significant interaction effect when threshed by tractor treading and stick beating whereas loss of germination percentage were 8 and 5.33 respectively (Figure 4). Because of the differences in threshing methods we wanted to determine the common beans seed quality implements. Results indicated that there were interaction effects of "varieties*threshing methods" that one or more of the varieties responded to the different threshing methods regarding seeds germination. This might be due to genetic characteristics of variety and methods of threshing that could be produced breaks, cracks, bruises and abrasions in seeds which in turn results in abnormal seedlings of questionable planting value. Similarly, information from [29] revealed that mechanical injury to seed not only reduces production of normal seedlings but also decreases the storage potential of damaged seed that apparently would have produced normal seedlings prior to storage. From the results it was suggested that in early generation seeds multiplication (EGSM); Nasser variety might be required other threshing methods to maximize standard germination and then increase seed production and productivity. Methods of threshing influence seed quality in terms of germination and vigour [30].

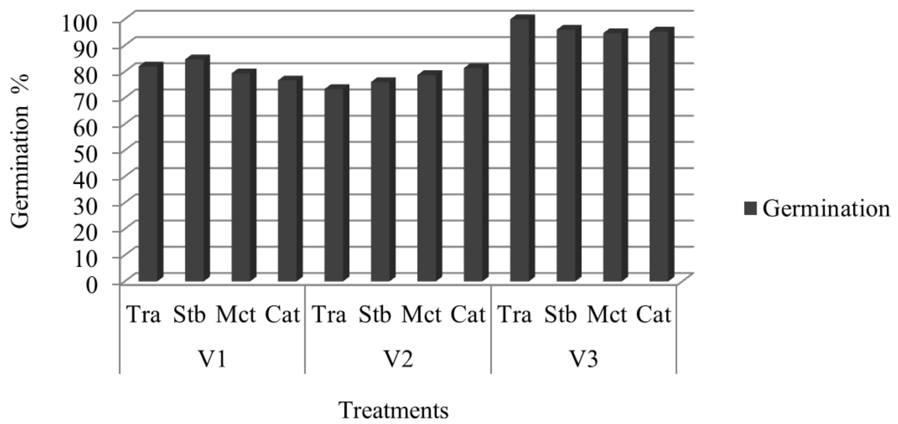

Figure 5. Mean percentage of 'varieties threshing methods' for seed germination.*

*Table 2. Interaction effect of 'varieties*threshing methods' by SG, MC & TSW.*

Varieties	Threshing methods	Tested seed quality parameters				
		SG%	Abs%	Ds%	MC%	TSW (g)
Awash-1	Tra	82cd	6.67ab	11.33ab	11.50ab	138.10d
	Stb	84.67c	6.67ab	8.67bc	11.10b	147.10d
	Mct	79.33de	8.67a	12.00ab	10.90b	141.77d
	Ca	76.67ef	8.00ab	15.33ab	12.10ab	182.33bc
Awash-2	Tra	73.33f	7.67ab	19.00a	12.00ab	176.43bc
	Stb	76ef	7.67ab	16.33ab	11.50ab	139.37d
	Mct	78.67de	7.67ab	13.67ab	11.43ab	175.30bc
	Ca	81.33cd	6.00abc	12.67ab	11.67ab	184.33b
Nasser	Tra	100a	0.00d	0.00d	12.70a	180.57bc
	Stb	96ab	1.00cd	3.00cd	11.60ab	175.67bc
	Mct	94.67b	2.67bcd	2.67cd	11.53ab	173.67c
	Ca	95.33b	2.67bcd	2.00cd	11.93ab	194.37a
HSD 5%		4.63**	5.65ns	8.28*	1.37ns	9.62**
CV%		3.22	34.98	28.69	3.96	1.94
Grand means		84.83	5.44	9.72	11.66	167.42

Tra= Tracter, Stb= Stick beating, Mct= Multi crop thresher, Ca= Cattle, SG= Standard germination, Abs= Abnormal seedlings, Ds= Dead seeds, MC= Moisture contents, TSW= Thousand seed weight. Means followed by the same letter within the same column are not significantly different at 5% level of probability, according to hsd test.

Seed vigour tests: In laboratory the standard germination test was only distinguished between normal and abnormal seedlings. However, it frequently produced results that over-estimate seed performance under less favorable environmental conditions. The variation in seedling size and vigour are likely to occur within the category of "normal seedling". Various studies indicated that the use of vigour tests has been useful to identify consistent differences in the performance of seed lots under a wide range of environmental conditions [18]. Seed vigour could be determined by different seeds physiological test parameters that carried out at laboratory as follow:

Speed of germination: The result indicated that there was none significant differences observed among varieties and threshing methods regarding speed of germination of common bean seeds. There was significant ($P<0.01$) difference observed in days of emergence for speed of germination. As damaged seeds increased might be due to several threshing methods abnormal seedlings and dead seeds increased where speed of germination decreased. Among tested common bean varieties; Awash-2 variety had higher speed of germination than Nasser and Awash-1 varieties. Speed of germination was decreased significantly as days of emergence increased with the number of germinated seeds decreased slightly (Figure 7). Similarly, Maguire [19] reported that speed of germination was calculated by dividing the number of seedlings counted each day for number of the days in which they were counted. There were none significant interaction effect among varieties and days of emergence regarding speed of germination. Numerically Nasser variety showed highest speed of germination at the day of 1st counted followed by Awash-2 variety whereas Awash-1 variety showed the lowest speed of germination while counted at the 1st day (Figure 6).

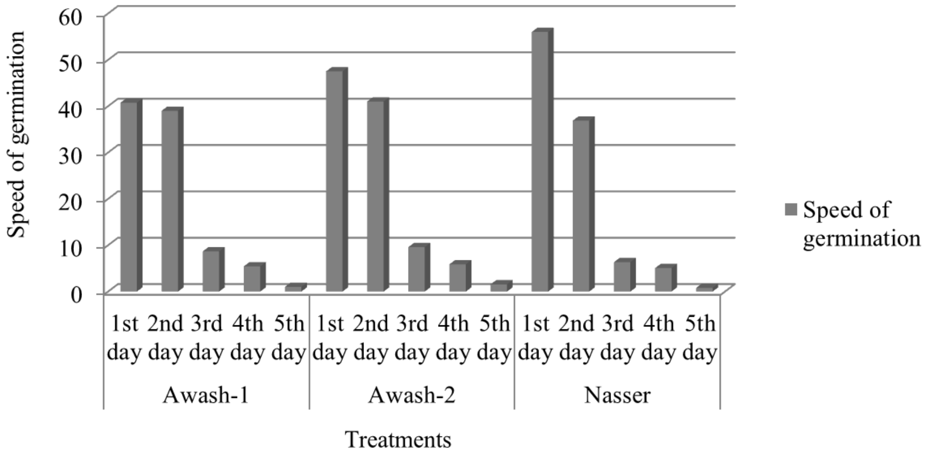

Figure 6. *Effects of 'varieties*seeds emergence days' for speed of germination.*

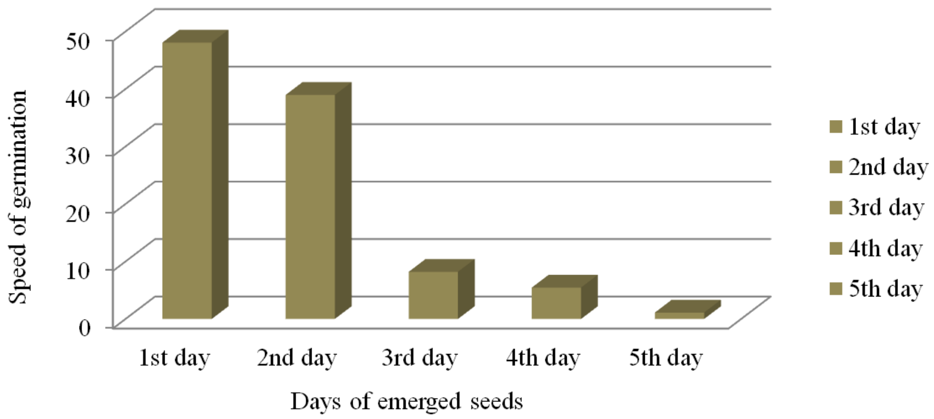

Figure 7. *Speed of germination with the number of emergence days.*

Seedlings shoot and root lengths: The seedling shoots and roots lengths were measured after the final count of standard germination test. The results indicated that there were high significant ($P<0.05$) interaction effects between variety and threshing method regarding average seedling shoot and root lengths. The highest mean of shoot length was recorded in

Nasser (27 cm) variety threshed by stick beating followed by same (25.67 cm) variety with tractor treading. The lowest mean of shoot length was recorded in Awash-2 (21.27 cm) variety threshed by multi crop thresher followed by Nasser (22.67 cm) variety threshed by the same thresher. The differences might be due to genetic features of the varieties and threshing methods. As thresher's weight and dram speed varies, the quality of threshing was also different that affect seeds quality. There were high significant ($P<0.05$) interaction effects of 'variety*threshing methods' for mean of seedlings root lengths. The highest mean of root length was recorded in Awash-1 (19.50 cm) variety threshed by stick beating followed by Awash-2 (18.80 cm) variety threshed by the same threshing methods. The current work findings are agreed with a study on common bean seeds samples produced under sole crop cropping system had relatively longer average root length (17.5 cm) than those produced under intercrop cropping system (17.0 cm). The average shoot length of seeds produced under sole (23.0 cm) and intercrop (22.5 cm) cropping systems were analogous [31].

Seedling dry weight: The seedlings dry weights were measured after the final count in the standard germination test. The results indicated that there were none significant interaction effects of 'variety *threshing method' for mean of seedling dry weight. There were none significant differences observed among varieties and threshing methods by means of seedling dry weight. However, numerically higher seedling dry weight mean was recorded in Awash-2 variety (0.80 g) followed by Nasser variety (0.76 g) whereas the lowest seedling dry weight mean was recorded in Awash-1 variety (0.75 g) (Table 5). Hence, Awash-2 seed variety had higher vigourisity than Nasser and Awash-1 irrespective of threshing methods. The difference in seedling dry weight of common bean seeds may be attributed to differences in genetic variation, threshing methods and moisture contents of the seeds. Similar study on common bean seeds revealed that seedling dry weight of seeds produced under sole crop (0.78 g) was relatively heavier than that of produced under intercrop cropping system (0.76 g) [31]. The difference in physiological quality of common bean seed of different sources may be attributed to differences in storage age and temperatures, seed moisture content in storage as well growers' level of awareness on seed production and handling [32]. The seed exhibiting maximum seedling dry weight is considered as vigorous [19].

Vigour indices:

Vigour index-I and II:

The results indicated that there was high significant ($P<0.05$) interaction effects of 'varieties*threshing methods' for seed vigour index-I (VGI-I) whereas none significant interaction effect observed for vigour index-II (VGI-II). Different threshing methods responded differently on seed quality of various common bean varieties. Nasser variety threshed by tractor treading exhibited high significant ($P<0.05$) interaction effects for VGI-I followed by same variety threshed by stick beating (Table 3). The higher the vigour index of the variety had the higher seed quality whereas the lower the vigour index of the variety had poor seed quality. Nasser seed variety showed significantly higher vigour index-I (2042.2) than the rest two varieties irrespective of threshing methods again. The vigour index-I of common bean seed threshed by tractor treading showed high significant ($P<0.05$) difference irrespective of varieties. Nasser seed variety showed significantly higher vigour index-II (73.27) than the rest two varieties irrespective of threshing methods. Similarly, Shelar [33] reported that, the vigour index of soybean seed threshed by stick beating and processed manually was significantly higher than that of seeds threshed and processed by machine irrespective of varieties.

Table 3. *Interaction effect of 'varieties*threshing methods' by SL, RL, VI-I, VI-II and SDW.*

Varieties	Threshing methods	Tested seed quality parameters				
		SL (cm)	RL (cm)	VGI-I	VGI-II	SDW (g)
Awash-1	Tra	24.17ab	18.17abc	1735.70bcd	57.55ab	0.70a
	Stb	23.50ab	19.50a	1819.70bc	68.48ab	0.81a
	Mct	25.53ab	16.17bc	1654.30cd	54.57b	0.69a
	Ca	24.93ab	16.43abc	1585.10cd	60.63ab	0.79a
Awash-2	Tra	23.33ab	18.37abc	1528.20d	59.23ab	0.81a
	Stb	24.50ab	18.80ab	1646.40cd	64.17ab	0.84a
	Mct	21.27b	18.33abc	1558.70cd	61.81ab	0.79a
	Ca	25.23ab	17.77abc	1746.70bcd	61.61ab	0.76a
Nasser	Tra	25.67ab	18.43ab	2205.00a	74.00a	0.74a
	Stb	27.00a	17.97abc	2158.40a	73.92a	0.77a

Varieties	Threshing methods	Tested seed quality parameters				
		SL (cm)	RL (cm)	VGI-I	VGI-II	SDW (g)
	Mct	22.67ab	15.27c	1794.30bcd	70.45ab	0.74a
	Ca	24.00ab	18.20abc	2011.30ab	74.69a	0.78a
HSD 5%		5.20*	3.14*	279.15**	19.08ns	0.24ns
CV%		7.20	5.94	5.26	9.87	10.39
Grand means		24.32	17.78	1787	65.09	0.77

Tra= Tracter, Stb= Stick beating, Mct= Multi crop thresher, Ca= Cattle, SL= Shoot length, RL= Root length, VGI-I= Vigour index-I, VGI-II= Vigour index-II, SDW= Seedlings dry weight.
Means followed by the same letter within the same column are not significantly different at 5% level of probability, according to hsd test.

Seed healthy test: Major seed borne fungi pathogens detected from Awash-1 seeds of common bean variety on Potato Dextrose Agar (PDA) plate were *Pencilium, Aspergilus Spp., Anthracnose* and *Phomosis* whereas detected bacterial pathogens on Nutrient Agar (NA) plate media were Halo blight and Common bacterial blight (CBB). Detected seed borne fungi pathogens from Awash-2 seeds were *Pencilium, Aspergilus Spp., Trichothecium, Fusarium* whereas detected bacterial pathogens on Nutrient Agar (NA) plate media was Halo blight. Seed borne fungi pathogens detected from Nasser seed common bean variety were *Alternaria, Fusarium, Aspergilus Spp., Pencilium, Macrophoma* and Halo blight was bacterial pathogens detected from this variety. There was significant difference among common bean varieties in percentage of infected seeds samples taken from seeds produced at Melkassa Agricultural Research Center (MARC). Seed borne pathogens associated with common bean seeds were detected from three varieties. Percentage of diseases incidence detected from Awash-1 (93.70) variety was higher than Nasser (86.70) and Awash-2 (64.30) varieties irrespective of threshing methods (Table 4).

The incidence of pathogens varied among varieties may be due to genetic variation and threshing methods. Among the many factors that affect common bean seeds threshing methods is the major one. Threshing methods may be cause primary infection on common bean seeds while threshing whereas secondary infection that caused by pathogens continued. The current work findings agreed with the study conducted on common bean seeds that detected seed born fungi pathogens associated seeds were *Chaetomium, Phoma, Alternaria, Aspergillus, Fusarium, Rhizopus, Penicillium, Aspergillus flavus, Aspergillus niger, Aspergillus ochraceus, Aspergillus parasitica, Rhizoctonia bataticola* and *Rhizoctonia solani*. Common bacterial blight (CBB) caused by *Xanthomonas campestris pv. phaseoli* or *Xanthomonas axonopodis cv phaseoli* was the only bacterial disease found associated with bean seed samples [31]. Similar study conducted on common bean seed quality of different formal and informal sources from the Central Rift Valley of Ethiopia indicated that *Fusarium oxysporium* and *Aspergillus* spp. were the two most common fungal diseases associated with seeds retained by farmers (own saved seeds) and those sampled from markets and cooperative unions [32].

Table 4. *Percentage of diseases incidences, common bean varieties and identified diseases.*

Common bean varieties	Identified pathogens	Diseases incidences (%)
Awash-1	Pencilium, Aspergilus Spp., Halo blight, CBB, Anthracnose, Phomosis	93.70
Awash-2	Pencilium, Aspergilus Spp., Trichothecium, Fusarium, Halo blight	64.30
Nasser	Alternaria, Fusarium, Aspergilus Spp., Pencilium, Macrophoma, Halo blight	86.70
Mean		81.57
Standard deviation		15.36

4. Summary and Conclusion

Currently producing and maintaining high quality seeds of various crops are pertinent issue in the seed sector to increase productivity and then secure seeds, nutrition and feeds for the country. Among the many factors affecting seed quality; methods of threshing and genetic characteristics of crop varieties are very important. Commonly for most of tested seed quality parameters the interaction effect of variety with threshing method indicated that one or more of the varieties responded to the different results of tested seed quality parameters in all threshing methods. This study indicated that threshing of some popular common bean varieties by manual and mechanical threshing methods at average seed moisture content (SMC) of 11.40-11.94% lead to significant and insignificant results of seed yields and tested seed quality parameters. Seed yields indicated that there were high significant ($p<0.01$) variation exhibited among varieties for seed yields. Even though the same agronomic practices have been done to all varieties, the seeds yield differences might be due to genetic potential of the varieties and environmental factors as well. Quantity losses caused due to threshing methods of common bean seeds were assessed through evaluating damaged seeds by visual observation of seed samples collected from each variety. Different threshing methods responded differently on tested seed quality parameters for various common bean varieties.

Mechanical threshing was made to enhance seed quality and reduce seed quantity loss, multi crop thresher exposed some seeds to damages which reduce seed quality due to internal and external damages occurred during threshing. Cattle treading showed higher seed purity than tractor trampling, stick beating by man power and multi crop thresher regardless of varieties. Differences among the varieties were significant ($P<0.05$) for percentage of pure seeds whereas none significant difference among threshing methods. There were high significant ($P<0.01$) interaction effects of ‘variety with threshing method’ regarding thousand seed weight whereas no significant interaction effects observed between variety and threshing methods regarding seed moisture contents (SMC). High significant ($P<0.01$) differences obtained among common bean varieties whereas none significant differences among threshing methods. There was significant ($P<0.01$) interaction effect between varieties and threshing methods regarding seeds germination. There was significant ($P<0.01$) difference in days of emergence for speed of germination. Speed of germination was decreased significantly as days of emergence increased with the number of germinated seeds decreased slightly. There was high significant ($P<0.05$) interaction effects of ‘varieties*threshing methods’ for seed vigour index-I (VGI-I) whereas none significant interaction effect observed for vigour index-II (VGI-II). Seed borne pathogens associated with common bean seeds were detected from common bean varieties that varied in incidence.

In conclusion, among tested common bean varieties, Nasser showed high significant interaction effects when threshed by portable multi crop thresher that have caused loss of germination (5.33%). Common bean variety (Nasser) threshed by mechanical thresher and post-harvest conditioned, evaluation of germination percentages, in addition to seed and seedling vigour measurements might be reliable indicators for seed quality and quantity losses. Thus, results suggested that to maximize percentage of normal seedlings Nasser variety might be required either other threshing methods or modification of existing multi crop thresher based on the size of common bean varieties. Maintenance of thresher efficiency of multi crops thresher to avoid visible and invisible seed damage that caused common bean quantity and quality loss. Some genotypes are resistance to mechanical damage and low rate of deterioration that could be recommended for further early generation seed multiplication and supply. Hence, Awash-2 is considered as a more "resistor" to damages caused by mechanical thresher. Threshing methods required critical selection and evaluation to identify appropriate threshers related with efficiency, effectiveness and seeds sizes. Multi crops thresher is assumed to be minimized seed losses and maintained seed quality of selected common bean varieties with optimum seed moisture contents while seed sizes and time of threshing might be required some modification. Further study should be conducted to identify appropriate threshing methods for each common bean varieties released for commercial purposes.

Abbreviations

MARC	Melkassa Agricultural Research Center
EIAR	Ethiopian Institute of Agricultural Research
SMC	Seed Moisture Content
VGI	Vigour Index
m.a.s.l.	Meter Above Sea Level
SNNPR	Southern Nations, Nationalities and Peoples Region

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Conflicts of Interest

The authors declare no conflicts of interest.

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