Performance Evaluation of Seed Cleaning Machines: A Case of Oromia Seed Enterprise

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DEPARTMENT OF MECHANICAL SYSTEM AND VEHICLE ENGINEERING

SCHOOL OF MECHANICAL, CHEMICAL AND MATERIAL ENGINEERING

A thesis submitted in Partial Fulfillment of the requirements for the award of Masters of Science degree in Agricultural Machinery Engineering

Office of Graduate studies

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Approval sheet

As members of the Board of Examiners of the M.Sc. thesis open defense, by Gemeda Tsegaye we have read and examined his thesis entitled on the "**Performance Evaluation of Seed Cleaning Machine".** This is therefore, to certify that thesis has been accepted in partial fulfillment of the requirement of the Degree of Masters in Agricultural Machinery Engineering.

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LIST OF ACRONYM

AAMRC	Asella Agricultural Mechanization Research Center
ASME	American Society of Mechanical Engineers
EATA	Ethiopian Agricultural Transformation Agency
FR	Feed Rate
OARI	Oromia Agricultural Research Institute
SGA2000	Sasakawa Global Africa 2000
HD114	Asasa Delta seed cleaner
DD114	Dodola delta seed cleaner
USDA	United State Department of Agriculture
OSE	Oromiya Seed Enterprise
Oe	Overall machine efficiency
Rey	Recovery in (%)
CE	Cleaning efficiency in (%)
Sl	Separation Loss in (%)
Cl	Cleaning Loss in (%)
η_L	Removal efficiency of light materials (%)
η_F	Removal efficiency of foreign materials (%)
η_B	Removal efficiency of broken materials (%)
(LM) out	Mass of light materials removed from samples
(FM) out	Mass of foreign materials removed from samples
Rey	Seed recovery (%)
(BSSP) out	Mass of broken, shrunken, shriveled kernels or powdered.
Mc	Machine capacity

ABSTRACT

Seed processing is a vital part of the total technology involved in making available high quality seed. For any processing it needs seed cleaning machine which has high accuracy, optimal efficiency in a vast range of work with a low noise level. Oromia Seed Enterprise has seed cleaning machines which need performance evaluation and tests. The evaluations and tests are necessary to maximize the efficiency of the seed enterprise and be able to use its machines to their maximum capacity for profitability. Thus, this thesis has been done to conduct performance evaluation of two Delta 114 cleaning machines of Oromia Seed Enterprise at Hasasa and Dodola site and recommend the optimum working conditions. Under different feeding mass and three types of seed all cleaning efficiency and loss, seed recovery, machine capacity and overall machine capacity were determined. The Average cleaning efficiency 96.89, 92.99 and 80.99 in percent and Cleaning loss 3.22, 7.56 and 24.76 in percent for Hasasa and Dodola center seed cleaner gave 95.5, 95.65 and 80.99 cleaning efficiency and 4.8, 4.57 and 23.54 cleaning loss during our evaluation on wheat, barley and bean cleaning respectively. The overall efficiency of Hasasa seed cleaner was 89.75, 77.89 and 73.27 and Dodola seed cleaner was gave 81.03, 80.35 and 49.86 overall efficiency on wheat, barley and bean respectively. The average seed recovery of machine for Hasasa was 92.6, 83.7 and 91.43 in percent and Dodola center seed cleaner gave 84.83, 84.03 and 61.44 seed recovery on wheat, barley and bean respectively. From evaluation carried out, we have seen that both seed cleaners give maximum performance during cereal cleaning and they have highest performance during wheat cleaning among cereals. However, both machines showed highest seed lost during bean cleaning and hence Oromia Seed Enterprise seed machines recommended for wheat and barley cleaning, and they need to further explore the possible adjustments and repair and maintenance issues for bean cleaning.

***Key word**: HD114, DD114, Cleaning efficiency, overall efficiency, cleaning loss, feeding mass/rate, and machine capacity and performance.*

CHAPTER 1

INTRODUCTION

1.1. Background

Africa with its vast land area covering 3 billion hectares has 1.3 billion hectares of agricultural land out of which only 252 million hectares (19.36%) is arable (FAO, 2011). Africa is the center of origin and also a major producer of several cereals like maize, soybeans, sorghum, pearl millet, Mellon, finger millet, and African rice. Maize has overtaken these traditional cereals while wheat is widely cultivated in North Africa and in Sudan and Ethiopia (Aremu *et. al,* 2015). Agriculture is the 'engine for growth' in Africa. With subsistence agriculture practiced by majority small holder farmers, yield gaps are high and poor soils, amongst other constraints add to the difficulties for sustainable farming and incomes. Cereals like sorghum, millets, wheat, maize and rice are major staple foods of the most population (Macauley, 2015).

These cereals are grown over an area of 98.6 million hectares producing 162 million tons. Cereals are grains or edible seeds of the grass family, Gramineae. Cereals are grown for their highly nutritious edible seeds, which are often referred to as grains. Some cereals have been staple foods both directly for human consumption and indirectly via livestock feed since the beginning of civilization (BNF, 1994). Cereals are the most important sources of food and cereal based foods are a major source of energy, protein, vitamins and minerals for the world population. Generally, cereals are cheap to produce, easily stored and transported, and do not deteriorate readily if kept dry (FAO, 2000).

Post-harvest losses are one of the enemies of farmers as food lost from one stage to the other during handling (Oladimeji *et al.*, 2019). Reducing post-harvest losses in seed processing industries is an important step toward ensuring greater global food grain purity as increased future demand will require increased production efficiency. Seed processing is a vital part of the total technology involved in making available high quality seed. It assures the end users, seeds of high quality with minimum adulteration. In Agriculture, the term seed processing includes cleaning, drying, seed treatment, packaging and storage.

In other hand it is impossible to grow and harvest seed crops without getting undesirable intermixtures despite proper care and tending of the crop. These intermixtures may comprise weed seeds, other crop seeds, and various inert matter as well as undeveloped seeds of species in question (Hana, Ahmed and Ashmawy, 2010). Seed processing may be understood to ‘comprise all the operations after harvest that aim at maximizing seed viability, vigor and health (Shiksha, 2020). New and improved crop varieties become an important agricultural input only when seed of such varieties are available to farmers variedly pure, in a viable condition, free of contaminating weed seed and in adequate quantities at the right place and time (Vaughan et al., 1968). Quality seeds are the basic requirement for sustainable agriculture. Quality seed alone can be enhance 15 to 20 percent of productivity (Pital et al., 2014).

It is estimated that quality seed under optimum management may contribute to the tune of 45% of total crop production. Worldwide seed processing industry is multibillion-dollar business, where billion tons of seeds have been processed every year (Ibid, 2014). Quality seeds with higher germination and vigor fetches 30% to 50% more price in market & also help to improve brand image of company in the market. Quality seed denotes the seed of improved variety having high physical and genetic purity, high germination rate, and great vigor, free from seed borne disease pests, need based value addition and long shelf life and high storability (Pital et al., 2014). To cope up with the increasing demand of quality seed there is need to do scientific analysis of grading machines and study the parameters responsible for effective grading of seed. The term seed processing plant refers to sequential set up of Seed cleaners, graders, Gravity separators, seed treaters and packing machine (Pital et al., 2014).

Seed cleaning is an important operation in a number of processes connected with the handling of seed after harvest. Annual report on Agriculture (2009-10) Hannaford Australia explains that heavy weighted seeds have more germination power than lighter seeds. That’s because seeds is the bridge between one generation of plant & the next. So seed grading is to maintain this quality from one season to next by removing all destructive elements such as other crop seeds, weed seeds, straw, and soil dust, immature, shriveled, damaged, cracked, undersize and oversized seeds. The cost of cultivating, fertilizing and controlling weeds in a paddock are high we cannot afford to permit faulty, foreign or diseased seeds to occupy our carefully prepared land (Pital et al., 2014)

Seeds grading has the smallest cost input in crop management but the highest return. Both expert official's tests & practical results have proved that proper seed grading gives a dramatic increase in yield (up to 45% better from large grain compared to small grain) (Ibid,2014). Seed with less than 80% emergence is not considered satisfactory and will require higher sowing rates to obtained optimum plant density (Baritone, 2016). As per research done by Colorado State University in 2008 on crop production, seeds are one of the least expensive but most important factors influencing crop yield potential. Seed quality is determined by many factors principally seed purity and germination. However many other factors, such as the verity, presence of seed-born disease, vigor of seed, and seed size are important when considering seed purchasing. The percentage by weight of crop seeds compared to other components. The best quality seeds are nearly 100% pure. To meet certified seeds standard for small grains, seeds must be more than 98% pure (Pital et al., 2014).

According to International Seed Testing Association (ISTA), seed quality depends upon seed size, color, diseased free seeds which directly relate to germination power of seeds. Seed processing is a wide spread area of interest in the Agricultural industry. For any seed handling process, whether it is cleaning, separating and sorting, or conditioning for further processing steps, there are time and cost penalties for at any level. Seed processing at the smaller scale must consider more strict physical and financial constraints (Baritone, 2016). An increase in cereal production and dynamic development of agricultural products creates a necessity to build modern and more efficient sorting–cleaning machines. The most widely used grain cleaner is an air-screen machine which separates according to the dimensions, shape, and terminal velocity of the grain particles (Wang, 2009).

A variety of equipment is available for processing seed. The choice of a machine or sequence of machines for processing seed depends on the kind of seed being processed, the nature and kinds of contaminants (weed seed, other crop seed, inert matter, etc.), the quantity of each in the raw seed, and the quality standards that must be met. Thus, the processor must be as familiar with seed standards and seed characteristics as he/she is with processing equipment (De Louche et al., 2008).

Seed cleaning machines for particular operations which prepare the raw material for processing is conditioned by a number of factors, including physical properties of the grain material, the level of cleaning accuracy, as well as the efficiency of a technological line. At the same time the machines are to be designed keeping in mind certain requirements such as high accuracy of sorting and cleaning, optimal efficiency, possibility to adjust in a vast range of work parameters, and a low noise level (Reichert, 1982). However, it is possible to separate the light materials from whole kernels using an aspirator or a combination of geometric properties (Chung, 2009).

Oromia Seed Enterprise (OSE) established by Oromia regional Government state at 2013 or 2006 E.C. Oromia Seed Enterprise (OSE) is one of the recently emerged, regional oriented public seed enterprises that involved in improved seed technologies producing and marketing with massive amount (Teferi, 2108). It has 3 branches: Bale, Arsi and Wellega. Oromia Seed Enterprise has seed cleaning machine from different center. This thesis was done to evaluate the performance of those Oromia seed enterprise seed cleaner machines.

1.2. Statement of the problem

Oromia Seed Enterprise has seed cleaning machines from different center for seed processing operation as they require performance evaluation. These seed cleaning machines play key role in daily work of Oromia Seed Enterprise. However Oromia Seed Enterprise didn't has clear data about performance of those seed cleaning machines. And no researcher who applied his/her research on performance evaluation these machines. In order to know performance these cleaning machines we have to evaluate they based on their efficiency, loss, capacity, seed recovery and overall efficiency. Unless the performance of these machine is determined it affect the productivity of Oromia Seed Enterprise and its profit in a negative way. The purpose of this thesis was to solve the mentioned problem and make recommendations for efficient utilization of the seed cleaners!

1.3. Objectives of studies

1.3.1. General objective

- To evaluate performance of Oromia Seed Enterprise seed cleaning and grading machines.

1.3.2. Specific objectives

- To conduct performance evaluation for the selected seed cleaner machines for wheat, barley and bean crops.
- To analyze the evaluation results statistically for machine using different parameters.
- To compare efficiency and performance of existing machine with predetermined standard.

1.4. Scope and limitation of the study

This thesis done in wide range. However, there was some parameter must be measured with precise instrument. If it is possible we recommended another researcher to does his/her researcher on measuring accuracy, noise and energy use of machine in required times with advance apparatus because we can't obtain those machine in local area. We recommend also advance work on our thesis with experienced researcher to strength what we have done. Because the performance any machines cannot determined by single research work. For deficiency of time there are some variable which we did not work on them. We recommended another researcher if they work on the parameters which we did not mention them in these thesis work.

1.5. Significance of the study

- The result of performance evaluation of seed cleaning machines may help to know and enhance the performance seed cleaner machines as well as it work as input for OSE to use their machine properly and as one standard when they buy cleaning machine for next time.
- The result might efficiently increase performance of those seed cleaner if it use as input to modify performance of machines for next year.
- It provides documented information about performance of Oromia Seed Enterprise seed cleaning machines for anyone who are interested research.

CHAPTER 2

LITERATURE REVIEW

2.1. Function of seed processing machines

Seed is main important input for agricultural production and they carry important genetic information of which the desirable types can be expressed under well-organized production well know. And the productivity of good crop cannot be expected without availability of good seed. Furthermore, clean seeds of improved varieties need to be maintained under specific conditions to produce quality seeds by farmer. The function of seed processing is to remove unwanted material from pure seed such like broken and shrunken, chaffs, weed seed, and others. Total mass of impurities in the seed samples consisted of three fractions; namely, light materials (LM), foreign materials (FM), and broken, shrunken, and shriveled kernels or powdered particles (BSSP) (Wang, 2009).

The common foreign or undesirable material in seed must be removed by seed processing such like twigs, leaf and soil particles, empty and weed seeds, dust, chaff to reduce bulk, improve storability and make seed easier to handle during subsequent processes. The ideal cleaned seed is free from any other materials. The degree to which this is achieved is called the purity (cleaning efficiency), usually measured in percentage (Schmidt, 2000). In Agriculture, the term seed processing includes cleaning, drying, seed treatment, packaging and storage. It may be understand to comprise all the operations after harvest that aim at maximizing seed viability, vigor and health. Seed Cleaning refers to separation of contaminants from produce and complete removal of the contaminants so that the cleaned produce is free from re-contamination (Kajuna, 2001).

Separating process fraction the seed lot into two categories, one category containing the seed and the other containing inert matter like stem, leaves, dust, dirt, chaff, etc. to be discharged. There are methods that may separate the seed lot into several fractions with various purities. Intermediate fractions typically contain both seeds and inert matter and must be further cleaned (Schmidt, 2000). Basically, undesirable material can be separated from the seed if it differs in its physical characteristics such as size, shape, weight/mass and density or specific weight. And the more similar the impurities are to the seeds, the more difficult they are to remove/separate.

Variation in seed size and morphology of the seed adds another constraint to seed cleaning: the larger the variation in the seed lot, the more difficult it is to clean. Eliminating/taking out inert matter without eliminating seeds with different sizes is difficult for many species (Schmidt, 2000).

2.2. Selection of machine

While selecting a machine following points should be considered:

- The machine should ensure a reduction in labor expended on unit production.
- Differences in the physical and mechanical properties of the seeds. Machines based on only those properties should be selected where difference in property is more in grain and foreign matter.
- Depending upon the end use of the grain like for seed purpose, commercial use, food use, feed use etc.
- For high value crops, specific machines of low capacity may be selected whereas for low value grains higher capacity machine can be used.
- Plant capacity and plant size.
- Type of foreign matter present in the mixture.

2.3. Types of seed cleaning machines

The purpose of using seed cleaning and separating machines is to separate seed from material other than seed. A large number of research projects have been done on the analysis and evaluation of seed separation. The most widely used seed cleaner is an air-screen machine which separates according to the dimensions, shape, and terminal velocity of the seed particles. Some other types of machines separate seed kernels based on the electrical properties. They used physical and engineering property of seed such as seed shape, size, density, terminal velocity and angle of repose. There are many types of seed cleaning and grading machines namely: Mechanical, aerodynamic, Air-screen cleaners, specific gravity table methods, Velvet roll separator, and etc. According to Hauhouotb et al. (2000) many commercial cleaners incorporate more than one of these cleaning methods:

2.3.1. Aerodynamic (pneumatic) separator and cleaner

It is based on the differences in aerodynamic properties of the various constituents of the mixture. The aerodynamic properties of a particle depend upon its shape, size, density, surface and orientation with respect to air current.

These types of machines are using air to lift light, chaffy and dusty materials out of the seed while heavier materials move down ward. The seed in mixture must be accelerated as free dispersed bodies and does not as mat. It depends on the existence of a differential between suspension velocities of the material (Terminal velocity) of the component to be separated. Air flow either to suspend or blow lighter material is generated by natural or mechanical fun. However, the limitation of natural air current as a means of separation is the unpredictability in direction, speed and continuity of the air current (wind), and the high labor requirement and rather imprecise degree of separation (Aguirre and Garry, 1999).

Aerodynamic separators and cleaner are basically of two types, namely the vertical air stream and horizontal air stream separators (Goral and Callaghan, 1990). In the vertical air stream separator, air stream is flowing vertically against the injected mixed product such that heavy particles drop through the air (counter current flow) while the light materials move upward and are carried along by the air (concurrent flow). In the horizontal air stream separator, air is blown horizontally or at an inclined angle to the horizontal against mixed product injected along the vertical plane. The mixed products are displaced along the horizontal plane at various distances based on their aerodynamic properties (Gorial and Callagham, 1990).

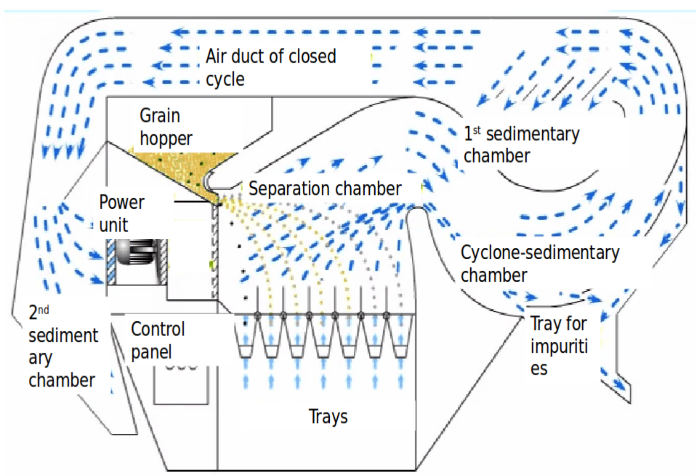

Figure 2.1. Aerodynamic separator and cleaner

2.3.2. Screen cleaner cum grader

It performs the separation according to the size and shape alone. The mixture of grain and foreign matter is dropped on a screening surface, which is vibrated either manually or mechanically. A single screen can make separation into two fractions. The screening unit may be composed of two or more screens as per the cleaning requirement.

This kind of machine is using the difference between sizes and shape of seed to separate desired material from undesired material. Both mixed material are moved over a perforated and oscillating surface with opening of specified shape and size. The two process that are occur during mechanical separation is segregation and separation take place along the sieve length as seed and material other than seed are being transported over sieve. The thickness and looseness of the seed and material other than seed layer on the sieve influences separation (Goral and Callaghan, 1990). The process of separation is ensured by the relative movement of layers of seed and undesired materials caused by the oscillation of plain sieves (Wang et al, 1994).

Figure 2.2. Mechanical seed cleaner

2.3.3. Air-screen cleaner cum grader

Combined air and sieve system, used to separate seed from undesired materials, employs terminal velocity, size, shape, and density as a means to segregation and separation. The method is advantageous and effective than the others methods of separation. The primary method of seed separating and cleaning, at the moment, is the air-sieve separator (OARI, 2006/7).

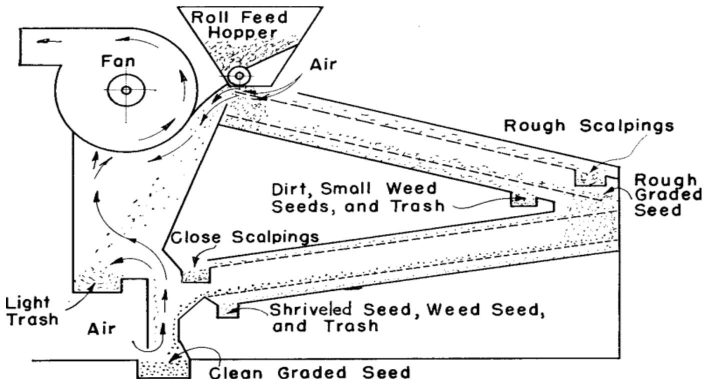

Figure 2.3. Mechanical aerodynamic seed cleaner

2.4. Factors affecting separating and cleaning efficiency

According to Simonyan et al. (2006) the physical parameters affecting the separating and cleaning process are grouped into two:

i. Machine factors such as frequency of sieve oscillations, amplitude of oscillation, sieve slope, length of sieve, width of sieve, sieve holes diameter, fan speed, angle/direction of airflow from the fan.
ii. Crop factors that include crop variety, maturity stage, seed moisture content, straw moisture content, bulk density of seed, bulk density of straw, stalk length, terminal velocities of particles (both seed and other materials), seed size and

2.4.1. Machine factors

Ebaid (2005) said that the cell shape, sieve tilt angle, sieve oscillation and air speed were the main factors that affect purity and total losses in cleaning. The purity increased by increasing air speed, sieve tilt angle and sieve oscillation. Total losses increased by increasing air speed, sieve tilt angle and oscillation.

2.4.1.1. Effect of sieve oscillation and sieve slope

Performance of seed cleaning and grading machine is affected by sieve slope, sieve oscillation and air speed. Sahay and Singh (1994) reported that there are different regime motions that can take place for rigid particles placed on a moving through depending upon the frequency of oscillation. Ismail (1986) stated that increasing the stroke length improved significantly the separation efficiency in both vertical and lateral motion at all sieve slopes, while in frontal motion, the separating efficiency decreased with the increase of stroke length at sieve slopes more than 15 degrees. In compound motions, an increase in stroke length caused a corresponding increase in separating efficiency especially in small sieves.

These three are the main factors that are affecting the efficiency of machine. With increment of air speed, sieve tilt angle and sieve oscillation separating and cleaning efficiency and total loss increased (Abayineh, 2015). According to Awady *et al.* (2003**)** cleaning efficiency and total losses were seriously affected by air speed, and sieve tilt angle. Abdel *et al*. (2007**)** reported that the slope of the sieve was the main factor that had a great effect on separation efficiency. The separation efficiency increased significantly with increase in sieve slope at small stroke length and decreased at high stroke lengths. In general, there was decrease in cleaning efficiency with increasing sieve oscillation frequency along the sieve length.

The decrease in cleaning efficiency with increasing sieve oscillations may be due to less resident time of materials to be separated on the sieve during cleaning. Harrison and Blecha (1983) described that the transport of particles along oscillating sieves, which is a function of sieve oscillation frequency, affects the efficiency of the process and affects metering of particulate substances along the sieve. Feller and Foux (1975) indicated that the frequency affects the passage of particles through the sieves. There was an increase inclining loss with increasing sieve oscillation frequency. According to Salwa et al. (2010) increasing the sieve oscillation from 26 Hz to 34 Hz considerably decreased the cleaning efficiency of fennel seed. In the cleaning system of cereal harvester having oscillatory sieves and also in vacuum separators frequency of oscillations were found to be the main factor that can appreciate the optimal efficiency of separation (Voicu *et al.*, 2007).

2.4.1.2. Effect of feeding rate

Inverse relationships had been reported between separating and cleaning efficiencies and feed rate. Decline in efficiency has been a common phenomenon with increasing feeding rate. The inverse relationship between cleaning efficiency and feed rate was indicated be due to the increasing load on the sieve that restricted free movement of seeds and undesired materials on grain such as *tef* (Abduljelil, 2010). He noted that a cleaning efficiency of teff cleaner machine was 40.13 % at the feed rate of 120 kg.hr^{-1} while the same efficiency declined to 36.83 % at the feed rate of 600 kg.hr^{-1} on *tef* cleaning machine. According to Awady et al (2003**)** cleaning efficiency and total losses were affected by increasing feed rate when cleaning rice (at higher feed rate, it required greater sieve length and took longer time for the seed to be separate from material other than seed.

This was considered to be due to the denseness of the material other than seed, which makes diffusion of the seed through it very difficult. The increase in cleaning loss with increasing feed rate was indicated to be due to high intensity of load with material other than seed on the sieve that had matting effect on the sieve and possibly blocked sieve holes (Awady *et al.,* 2003). Awady et al. (2003) further indicated that if feed rate is increased (higher), the materials are no longer supported aerodynamically, and form a mat on the sieve, increasing seed losses. Abduljelil (2010) indicated that there could be an increase in seed loss with increasing through put of material other than seed.

Faran and Macmillan (1979) confirmed that increasing material feed rate also increased the total head on the fan leading to a reduction in air velocity from the nominal value.

2.4.2. Material factors

Gumble and Maina (1990) indicated that physical and mechanical properties of seeds such as size, shape, density, angle of repose, coefficient of friction are important parameters and measured or estimated in order to design separating, cleaning, sizing and grading machines. The various material factors that affect the efficiency of a cleaner cum grader are as given below:

a) Compaction or bed density
b) Particle size, shape and other properties
c) Distribution of various fraction sizes
d) Stickiness and abrasiveness

2.4.2.1. Physical properties of seed and straw

Gumble and Maina (1990) indicated that physical and mechanical properties of seed such as size, shape, density, repose angle, coefficient of friction, tensile and compressive strengths are important parameters and be measured or estimated in order to measure the separating, cleaning, sizing and grading efficiency of machines.

2.4.2.2. Aerodynamic properties of seed and straw

Mohsenin (1978) indicate that separation of a product from its associated and yet undesirable materials, such as straw and chaff, in air stream, require knowledge of aerodynamic characteristics of all the particles involved. Furthermore, it was noted that a range of air velocities, for effective separation of the seed from material other than seed need to be estimated. As such, the terminal velocity (V_T) be used as an important aerodynamic characteristic of materials in pneumatic conveying and separation. Wu *et al*. (1999) and Solomon (2007) noted that by defining the terminal velocity of different threshed materials, it was possible to determine and set the maximum possible air velocity in which material other than seed can be removed without losses. Abduljelil (2010) found the terminal velocity of *tef* grain to increase from 3.24 m/s to 4.04 m/s with increasing moisture content from 11.94 % to 27.10 % (wb).

On the contrary, he noted that the drag coefficient was decreased from 0.76 to 0.66 with increasing in moisture content from 11.94 % to 27.10 %. Short straws are the major contaminant of threshed materials; they are very difficult to separate from the seed. Straws are neither symmetrical nor uniform, in density, and their lack of symmetry causes aerodynamic instability.

2.5. Sieving / screening

In sieving or screening, two types of screens, flat and rotary screens, are generally used. The screens are rotated or vibrated to bring all the particles into contact with the openings. For flat screen, three different mechanical motions are involved in the separation process. These motions are oscillation, vertical vibration, and gyration. The separation principles for both flat and vertical rotating screen are based on width and thickness of seed kernels. The indented cylinder and indent disk are the two general types of separators to separate particles based on length. The indented cylinder separator consists of a rotating, horizontal cylinder and a movable, horizontal separating trough.

The inside of the surface of the cylinder has small, closely spaced indentations that may be hemispherical, cylindrical or tapered. As the cylinder rotates on its axis, the short particles of a seed mixture that fit into the indentations are lifted and discharged into the trough (Brandenburg, 1977). Chung et al. (1986) conducted a research project named "Review of the State of the Art in seed cleaning". Information related to a total of 1,639 models of seed and seed cleaning equipment was collected from throughout the world based on a literature review and survey. It was found that 70% of the total models are of the following types: air-screen separator, screen separator, aspirator, indented cylinder separator, and rotary cylinder cleaner-grader.

Hashem and Eberhard (2007) reported that, the operation of particle separation is divided into two main categories, continuous and batch operations. In continuous operation, the particles are continuously fed into the separation unit during the whole separation process. This type of particle separation is usually called ‘screening’. On the other hand, batch operation is used if the particulate material is charged only once. This kind of batch separation is commonly described by the term ‘sieving’. Screens can be classified into three groups according to their mode of particle movement.

These groups are (a) vibrating screens in which the particulate material moves relative to the screen in a vertical plane, (b) flat screens in which the particulate material moves relative to the screen in the plane of the screen and (c) rotating screens in which the screen surface is cylindrical and the particulate material cascades over the inner surface as the screen is rotated. Amin (1994) developed and tested a grading machine consisting of rotating cylinder and performed concave to grade potato, onion and orange crops. The machine was tested in grading potato crop. The obtained results showed that crop parameters such as (tubers dimensions and mass) and machine parameters such as (cell area and shape, drum speed, slope of drum axle and drum length) had a significant effect on grading efficiency. The capacity of machine at optimum drum speed of 25 rpm and slope of zero degree was 1.2 Mg/h with tuber damage of 0.23%. Higher germination, seedling length and vigor index were noticed in medium sized seeds followed by bigger sized seeds as reported by Virendra Singh *et al*. (1995), and Ghosh *et al*. (1976).

Hurburgh *et al*, (1989) tested six rotary seed cleaner models for efficiency of removal of fine material from dry corn at various flow rates. They reported, removal efficiency for all sizes of particles generally declined as flow rate increased. Removal efficiency was lower for particles sizes closer to the screen opening size. Pierce (1985) reported that the rotary-type cleaner probably is most common for on-farm application. Rotary seed cleaners separate seed into size fractions by moving it through a trammel (revolving cylindrical screen with axis slightly inclined). As the trammel rotates, material cascades over its surface, and fine material passes through the screen. Material not passing through moves out the end of the trammel. Some cleaners employ a secondary trammel with larger openings for scalping (removal of material larger than the seed being cleaned). The secondary trammel may be concentric with or an extension of the first.

Pierce (2007) reported that models are available with increasing seed moisture, by decreasing trammel slope, by increasing fines content, and by certain seed types. Harrison and Blecha (1983) itemized parameters influencing sieving as size of the particle and sieve apertures, relative particle to sieve velocity, mean particle velocity and orientation of oblong particles. They also published that particle velocity is a function of frequency and amplitude of oscillation, sieve slope, hanger angle, friction between particle and sieve. Feller (1980) reported that, to evaluate screen performance, both partial passage and clogging of the screen should be considered.

A screen rate function, defined as the sum of the passage and clogging rate factor versus relative particle size, was developed to characterize screen performance. This function is independent of screen duration and can be used as a general expression that is not limited to a particular size distribution of the material or to one screen duration. Klein and Cakon (1980) reported some parameter to evaluate the efficiency of grading crop yield. These parameters are: separate the rubbish and haulm from the crop, grading crop yield, into three categories small, medium, and big with about (10 %) of weight interactions between any of two categories of them and the total damage in any group cannot be increased than 2 %. Metwalli (1975) designed and tested a horizontal cylindrical screen for seed-straw separation by centrifugal and gravity forces. The forces affecting the separation of the particles in a rotating horizontal screen were gravity force, centrifugal force and the normal force between the screen and the particles.

2.5.1. Screening surface and recommended sieve sizes for different seeds

The basic sieve for cleaning elongated seed is a slotted top sieve and a slotted bottom sieve. In special separations it may be necessary to pass such seed through round-hole top sieve or over some sieve other than a slotted bottom sieve, but generally, slotted top and bottom sieves are used (USDA, 1968). The screens are made from steel plates and are available with different sized perforations, including round and oblong (slotted), triangular, and wire mesh. The choice of screen type and holes size depends on the seed (variety and condition) to be cleaned. Two very similar screens may produce very different results in the quality of seed cleaning, depending on the individual lot.

Different seed lots even of the same variety may present major differences in terms of size of seed, impurities and weed seeds. Therefore, select a specific adapted set of screens for each seed lot. Screens do not last forever: over time, they bend and the flow of seed becomes concentrated towards the middle. This results in several layers of seed at the center of the screen and little or none at the edges. Uneven distribution of seed on the screen hinders the removal of impurities and the cleaning process is less efficient. Replace worn and damaged screens. Combinations of screens with different hole types may be used in a single operation, for example: for wheat seed, top screen with round holes (diameter $\leq$ 6.00 mm) and bottom screen with slotted holes (width $\geq$ 2.2 mm).

FAO (2012) recommends different sieves for different crops as follows:-

Table 2.1. Different screen recommended for different seed types

	Top screen			*Grading screen*		
Crop	***From***	***To***	***Hole type***	***From***	***To***	***Hole type***
Alfalfa	1.75	2	Round	0.5	0.6	Slotted
Barley	5.25	5.6	Round	2.1	2.3	Slotted
Bean	5.5	7	Round	3	4	Round
Maize (white dent)	8	11	Round	7.5 3.3	7 3.7	Round Slotted
Maize	7	9	Round	5 3	5.5 3.5	Round Slotted
Rice	5 2.5	5.5 2.8	Round Slotted	1.6	1.9	Slotted
Sorghum	4	4.5	Round	3 2.2	3.3 2.3	Round Slotted
Sorghum (Sudan)	3	4	Round	2.2 1.4	2.3 1.6	Round Slotted
Soy bean	10	9	Round	5.5 3.4	6.3 3.6	Round Slotted
Sun flower	5.5	7.5	Round	2.3	2.6	Slotted
Wheat	4.5	5	Round	2.1	2.3	Slotted

2.5.2. Effectiveness of screen

The screen effectiveness may be defined as the ability of a screen in closely separating the feed into overflow and underflow according to its size. If the screen functions properly, all material 'O' would be in the overflow, while all the material 'U' would be in the underflow. The materials balance in a screening operation can be derived as follows:

$$F = O + U \text{ -- } (1)$$

$$Fm_f = Om_o + U \text{ -- } (2)$$

Therefore,

$$\frac{O}{F} = \frac{m_f - m_u}{m_o - m_u} \text{ -- } (3)$$

$$\frac{U}{F} = \frac{m_o - m_f}{m_o - m_u} \text{ -- } (4)$$

A common measure of screen effectiveness is the ratio of actual amount of oversize materials in the overflow to the amount of oversize entering with the feed.

Thus,

$$E_0 = \frac{\mathbf{O}m_o}{Fm_f} \text{ ---------- } (5)$$

$$E_U = \frac{U(1-m_u)}{F(1-m_f)} \text{ ---------- } (6)$$

Overall effectiveness = E=$E_0 \times E_U$ ---------- (7)

Substituting the values we get,

$$E = \frac{(m_f - m_u)(m_o - m_t)m_o(1-m_u)}{(m_o - m_u)^2(1-m_t)m_f} \text{ ---------- } (8)$$

Where, E = Effectiveness of screen

F = mass flow rate of feed, ton.hr-1.

m_f = mass fraction of material in feed

m_o = mass fraction of material in overflow o

m_u= mass fraction of material in underflow.

O = feed in overflow

U = feed in underflow

2.6. Performance evaluation of seed cleaning machine

It will be considered the following specifications to be fulfilled about degree of cleanliness of seeds: Seeds must be cleaned from all normal odors and foreign seeds, and Seeds must be free from material other than seed and the maximum allowed foreign matter is 5% by weight. Chung and Lee (1985) studied the physical properties of rice and corn. They reviewed physical dimensions of seed, such as length, width and thickness, which varied according to the variety, environmental conditions, temperature, and moisture content. The true density ranges from 1019 ton/m^3 to 1387 ton/m^3 for rice, and 1190 ton/m^3 to about 1370 ton/m^3 for corn, depending on the variety and the variation in moisture content. Bilanski et al. (1962) measured the terminal velocities of one variety of wheat, barley, corn, soybeans, small and large oats, alfalfa, and flax in still air.

Song and Chung (1989) studied the physical properties and terminal velocities of various fractions in corn samples. The study showed that no machine can separate the impurity completely from a given seed sample without any seed loss because of the size distributions of the different fractions. However, it is possible to separate the light materials from whole kernels using an aspirator or a combination of geometric properties.

They also studied the effect of shape factor and Reynolds number on the drag coefficient of corn. Chung and Converse (1971) studied the effect of moisture content on some physical properties of corn and wheat. They studied the changes in these properties caused by changes in moisture content related to both adsorption and desorption of moisture, and examined the effect of kernel shape and size on corn packing characteristics. Chattopadhyay (1983) studied physical properties of bran rice germ and broken seed including average particle diameters, terminal velocity, and specific gravity. He found that moisture conditioning which raised moisture content could increase the terminal velocities of germs and broken and thus separation efficiency. Feller (1980) reported that, to evaluate screen performance, both partial passage and clogging of the screen should be considered.

A screen rate function, defined as the sum of the passage and clogging rate factor versus relative particle size, was developed to characterize screen performance. This function is independent of screen duration and can be used as a general expression that is not limited to a particular size distribution of the material or to one screen duration. Perry and Chilton (1973) reported that the optimum slope of inclined vibrating screen is that which handle the greatest volume of oversize and still remove the available undersize required by the standards of the particular operation. To separate a material into coarse and fine fraction, the bed thickness must be limited so vibration can stratify the load and allow fines to work their way to screen surface and pass through the opening. Increased slope naturally increases the rate of travel, and given rate it reduces the bed thickness.

Abd El-Tawwab et al (2007) reported that the slope of the sieve was the main factor that has a great effect on separation efficiency. The separation efficiency increased significantly with increase of sieve slope at small stroke length and decreased at high stroke lengths. In order to evaluate the performance of the cleaning unit, parameter cleanliness, seed recovery, and effectiveness were used. These criteria could be determined from the following relationships.

According to Kashayap and Pandya (1965):

$$\text{Cleanliness, \%} = \frac{a}{a+b} \quad (9)$$

$$\text{Seed recovery, \%} = \frac{a}{a+c} \quad (10)$$

$$\text{Effectiveness, \%} = \frac{d}{b+d} \quad (11)$$

Chaff rejected, % = $(\frac{a}{a+c})\ (\frac{d}{b+d})$ --- (12)

Where, a = seed recovery in the product.

b = straw and immature in the product.

c = seed in the reject

d = straw and immature in the reject.

Wang et al., (1994) and Negrini et al., (1994) evaluated a laboratory seed and separating equipment and found out the overall removal efficiency which is determined by calculating the material balance of as follow:

$$\eta_{\text{IMP}} = \frac{(\text{IMP})\ \text{in}}{(\text{IMP})\text{out}} \quad (13)$$

Where, η_{IMP} = overall removal efficiency (%)

$(\text{IMP})_{\text{in}}$ = total mass of impurities in test samples before separation (kg).

$(\text{IMP})_{\text{out}}$ = total mass of impurities removed from test samples (kg).

According to Wang (2009) total mass of impurities in the seed samples consisted of three fractions; namely, light materials (LM), foreign materials (FM), and broken, shrunken, and shriveled kernels or powdered particles (BSSP). In order to calculate the removal efficiency of each component of impurities, the following formulas have been used:-

$$\eta_L = \frac{(\text{LM})\text{out}}{(LM)_{in}} \times 100 \quad (14)$$

$$\eta_F = \frac{FM_{out}}{FM_{in}} \times 100 \quad (15)$$

$$\eta_B = \frac{BSSP_{out}}{BSSP_{in}} \times 100 \quad (16)$$

Where: η_L = removal efficiency of light materials (%)

η_F = removal efficiency of foreign materials (%)

η_B = removal efficiency of broken materials (%)

$(\text{LM})_{\text{out}}$ = mass of light materials removed from samples (kg)

$(\text{FM})_{\text{out}}$ = mass of foreign materials removed from samples (kg)

$(\text{BSSP})_{\text{out}}$ = mass of broken, shrunken, shriveled kernels or powdered particles removed from samples (kg)

2.6.1. Separation efficiency and separation loss of the machine

As per Amer (2009) separation efficiency and grain losses have been calculated using Equation (17, 18)

$$SE = \frac{M_1}{M_2} \times 100\ \% \text{--} (17)$$

$$SL = \frac{M_4 - M_3}{M_4} \times 100\% \text{--} (18)$$

Where: M_1= the mass of impurities after separation and cleaning (kg),

M2 = the mass of impurity before separation and cleaning (kg)

M3= the mass of seed grain after separation and cleaning (kg)

M4= the mass of seed grains before separation and cleaning (kg)

SE = Separation efficiency (%)

SL = Separation loss (%)

2.6.2. Cleaning efficiency and cleaning loss of machine

Cleaning efficiency is the ability of machine to produce clean seed at clean seed out let with minimum percentage of impurity. Cleaning efficiency of machine has been determined as follow (Simony and Yiljep, 2008):

$$CE = \frac{G_O}{G_o + C_{cg}} \times 100\ \% \text{--} (19)$$

Or

$$CE = \frac{M_{css}}{M_{sbc}} \times 100\ \% \text{--} (20)$$

Where, CE = Cleaning efficiency (%)

Go = Weight of pure seed at outlet (kg)

Ccg = weight of contaminated in cleaned seed (kg)

M_{css} = mass of clean grain sample (kg)

M_{sbc} = mass of sample before cleaning (kg)

The cleaning efficiency for an air-screen grain cleaner as suggested by the Bureau of Indian Standards (BIS) is given below (IS 5817:1980)

$$\text{Cleaning Efficiency} = \frac{E(F-G)(E-F)(1-G)}{F(E-G)^2(1-F)} \text{--} (21)$$

Where, E = fraction of clean seed at clean seed outlet

F = fraction of clean seed in feed

G = fraction of clean seed at foreign matter outlet

The cleaning loss will be calculated using the equations given by Webby (2010)

$$CL = CE\ (\frac{M_{CSS}}{M_{Sbc}} \text{ x } 100\%) \text{ -- } (22)$$

Where: Mcss = mass of clean seed sample (kg),

Msbc = mass of sample before cleaning (kg) and

CL = cleaning loss (%).

As we see in different scholar study and conclusion there many are ways to determine the efficiency of seed cleaning machine. But the very core idea were how to measure machine capacity, cleaning efficiency of machines were evaluated using parameters such as feeding mass rate, cleaning efficiencies and losses associated with overall machine efficiency.

CHAPTER 3

METHODOLOGY

3.1. Study area

This evaluation was done at Asasa and Dodola. **Hasasa** is a town in south eastern Ethiopia. Located in the West Arsi Zone of the Oromia Region, this town has a latitude and longitude of 07°06′N 39°12′E with an elevation of 2367 meters above sea level. It is the administrative center of Gedeb Hasasa woreda. **Dodola** is a town in south eastern Ethiopia. Located in the West Arsi Zone of the Oromia Region, this town has a latitude and longitude of 06°59′N 39°11′E, with an elevation ranging from 2362 to 2493 meters above sea level. It is the administrative center of Dodola woreda.

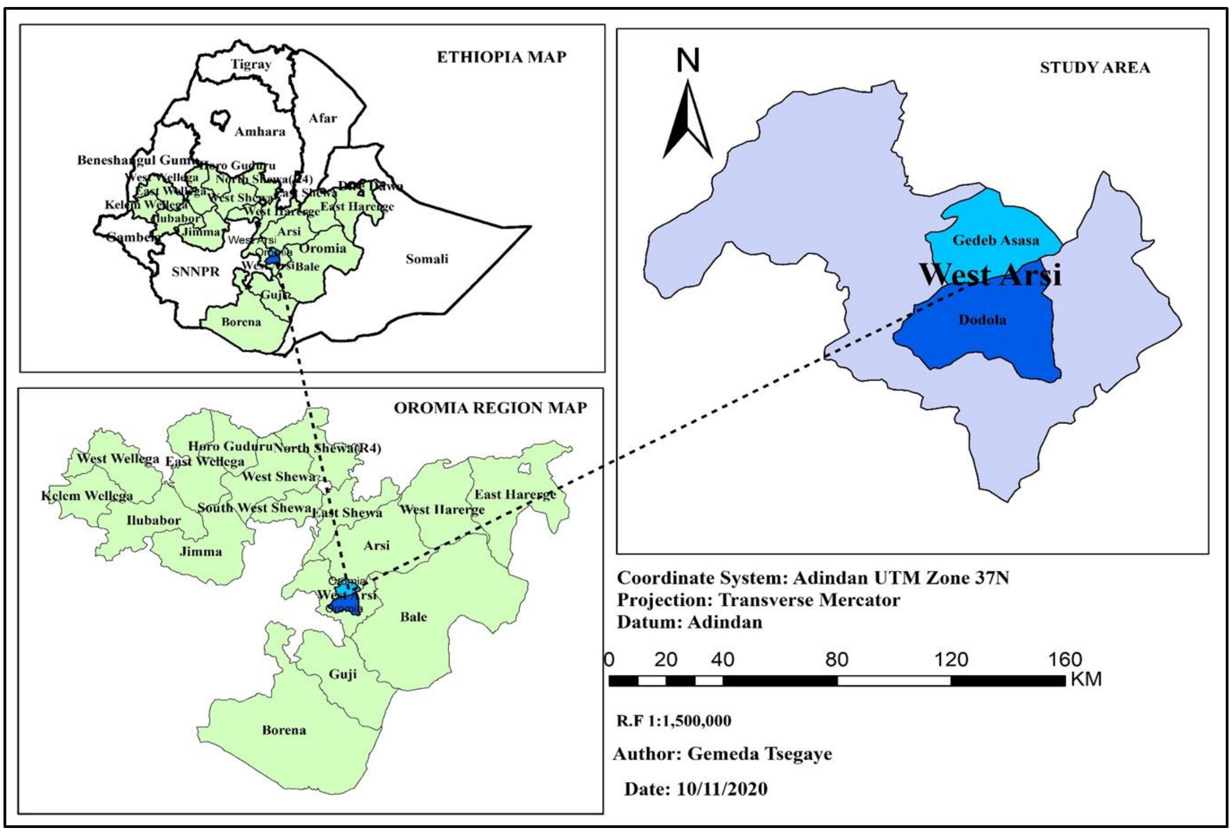

Figure 3.1 Gedeb Asasa and Dodola Woreda map

3.2.Experimental design

The experimental design was factorial in split-split plot, 3 x 3 x 3 having 27 experimental units. Each combination of an experiment (wheat x barley x bean) was replicated three times with total of test 81 test runs. The significant parameters that were investigated in this thesis are: - The 3 OSE seeds wheat, barley and bean were selected. The effect of feeding rate, the effect of seed variety on OSE Delta 114 cleaning efficiency and cleaning loss, percentage of seed recovery and overall machine efficiency by differing feeding mass rate and seed variety, the capacity of machine under different feeding rate within crop variety was determined.

Different amount of sample mass were used to evaluate performance of machine with heavy amount of mass and light amount of mass within each variety of seed. Two Delta 114 seed cleaning machine OSE seed process machines were selected coded with HD114 for OSE seed cleaning plant in Hasasa town and DD114 for OSE seed cleaning plant in Dodola town to analyze the performance both machines. The recorded data on input, output, impurity and loss of machine at different time, seed variety and seed from different field were used to evaluate the performance those OSE Delta 114 cleaning machines.

3.3. Experimental procedure

Adjustment of air, sieve oscillation and angle, and feed control of the seed cleaning machines was made. The two cleaning equipment were evaluated in the project site, in principle, air screen cleaning in which the impurities in seeds are separated through aspiration and screening, the settings of air and feed control significantly affect the removal efficiency of each cleaning unit. Air and feed control settings of the cleaning units were made according to the manufacturer's recommendation. In addition manufacturer's recommended setting were used, modifications on settings of aspirators and screens were made, based essentially on the following assumptions in order to evaluate the performance of each machines objectively:

- **Feed control**: It was adjusted automatically by computer which identifies the level of seed in seed tank through sensor. The sensor was gave three sign in different color. They bright red when seed in thank overfill and under fill. They lighted green when optimum level of seed is there in the seed tank. It was adjusted so that a seed sample of in ton passes through all sieves in predetermined minutes or less.

- **Air control**: It was adjusted by operator based on seed type and level of impurity by operator after looking at material other than seed exit. If there was eligible seed in impurity exit the operator was readjust air velocity of blowing fun at that moment. After that there are small remove sound kernels from the seed sample actually.
- **Sieve oscillation:** All 7 sieves of machines were oscillated as manual recommendation for each type of seed. Sieve oscillation were fixed for each seed types so the was no effect by variation of sieve oscillation under one required test operation.
- **Sieve slope:** The machine was built at fixed sieve slope. The operator was changed only sieve for required operation. In this case there was no great deal with sieve slope on performance of both machines at HD114 and DD114.

3.4. Preparation of samples

Clean seed was mixed with bulk of impurity that come from field after primary cleaning done by combiners. Before starting of cleaning and grading process the mass of mixture of clean seed and impurity were measured in Kilogram. Totally the sample contain clean seed and impurities namely, light materials, foreign materials, broken and shrunken kernels, and fine materials. All effect of sieve oscillation, angle and air velocity was maintained as manufacturer recommended. Under this procedure the performance of OSE cleaning machine were evaluated. The cleaning efficiency, seed recovery, machine capacity, overall efficiency and losses were determined as a whole.

3.5. Machine description

Table 3.1. Machine description

Brand	Model	Manufacturer	Country
Cimbria	Cimbiria Delta 114	Cimbria Plc	Denmark

Source: Cimbiria DELTA 114 manual.

3.5.1. The variety crop the machine can process

Cimbria Delta 114 should be clean wheat, oat, grass seed, soya bean, barley, peas, maize malt, rice, sunflower, rape seed and coffee.

3.5.2. Capacity

As manual recommendation for Cimbria capacity of machine at 15% H_2O; 10% of removal to EU standard is described as follow:-

Table 3.2. Capacity of Cimbria DELTA 114

Types of seed	**Capacity t/hr.**
Wheat, Rye, sorghum and malting	5.0
Oats, maize, white rice	4.0
Soya, peas. Rape and green coffee	4.0
Paddy rice	3.0
Sunflower, roasted coffee	2.0 – 2.5
Rye grass, clover and beet seed	0.75 – 1.0

Source: Cimbiria DELTA 114 manual.

3.6. Working principle of machines

3.6.1. Delta 114 seed cleaning unit

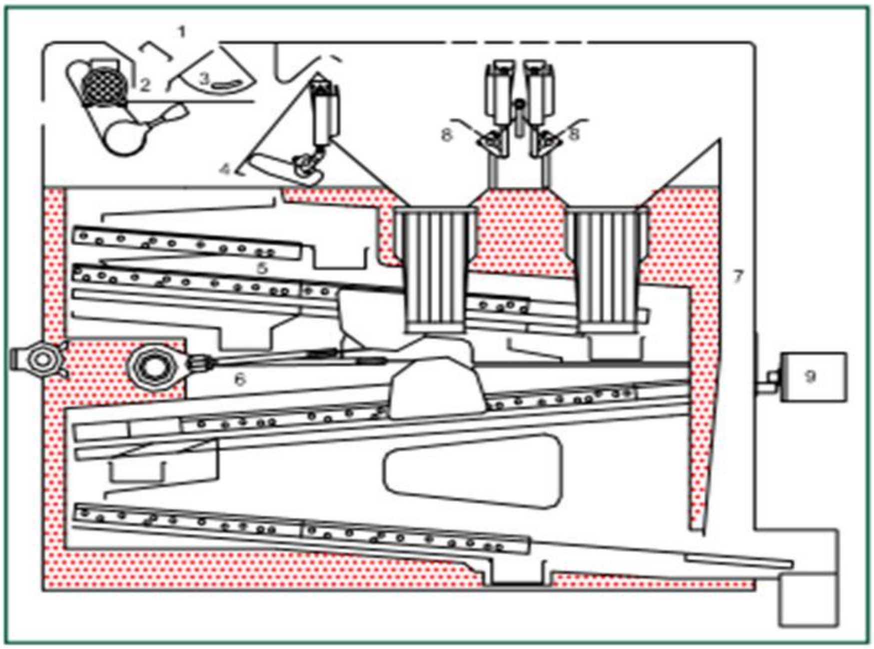

Figure 3.2. Schematic diagram of Delta 114 cleaner unit

As we can see from figure 3.2 all parts are explained as follow:

1) Inlet Optimal feed over the width of the machine is achieved by a shaker feeder with steeples adjustment via frequency regulation.
2) Shaker feeder: ensures an uniform feeding on the entire width of the machine also when cleaning difficult flowing products, i.e. grass seed, in addition the shaker feeder also prevent the product from flowing when the shaker feeder has stopped.
3) Adjustable feed gate: the feed gate will only be adjusted when the opening need to be bigger due to difficult flowing products, i.e. grass seed.

4) Pre-suction: with finely adjustable suction intake directly under the feed gate for effective removal of fine particles.
5) Screens: can be employed as sieves, sorters or graders, and are effectively kept clean by rubber balls in newly developed ball boxes. It is not necessary to take out the ball boxes when changing screens.
6) Eccentric drive system: for screen boats Supplied standard with fixed speed or alternative frequency regulation.
7) After suction: light particles are sucked out of the product flow on the air screen and lead through the lifting air channel to the expansion chamber, from where it is extracted by screw conveyor.
8) False air intakes (2pcs.): for adjustment of air quantity in both the pre- and after suction systems.
9) Adjustment: remote control of integral motor for shaker feeder, pre suction, after suction and air velocity. The adjustment of the above is placed in a small control box, which is placed on the cleaner.

3.6.2. Indent cylinder

The Cimbria indented cylinder separator is used for length grading of all granular materials, such as wheat, oat, maize, rice, fine seeds, lentils, sticks from sunflower or sugar beet, plastic particles, etc., as well as for the extraction of unwanted short or long admixtures. Depending on the required grading; the incoming product is sorted according to roundness or length.

Figure 3.3. Indented cylinder

3.6.3. Dram grader

This grader used to separate different seed in to different grade based on their physical property basically by using their shape and size. It does work to grade large and small size seed in different fraction.

Figure 3.4. Dram grader

3.6.4. Gravity separator

This unit separate seed in different class based on their density and weight. All immature seed and weed seed, broken and light weight seed leave the end product by help of this unit. The only eligible seed and good seed passed in to filler. The gravity separator cannot replace these earlier sorting steps, but is an additional piece of equipment for separating more accurately according to specific weight.

Figure 3.5. Gravity separator

3.6.5. Filler

The filler used to put end product into bag based on the need. It can produce 25kg or 50kg bag of seed based on demand.

Figure3.6. Filler

3.6.6. Cyclone fan

The great function of cyclone fun is absorbing debris, leaf, seed coat and light weighted seed including weed seed from pure seed. It is constructed with electric motor and negative pressurized suction fan. It absorbs all unnecessary light material and less weighting seeds.

Figure 3.7. Cyclone fan

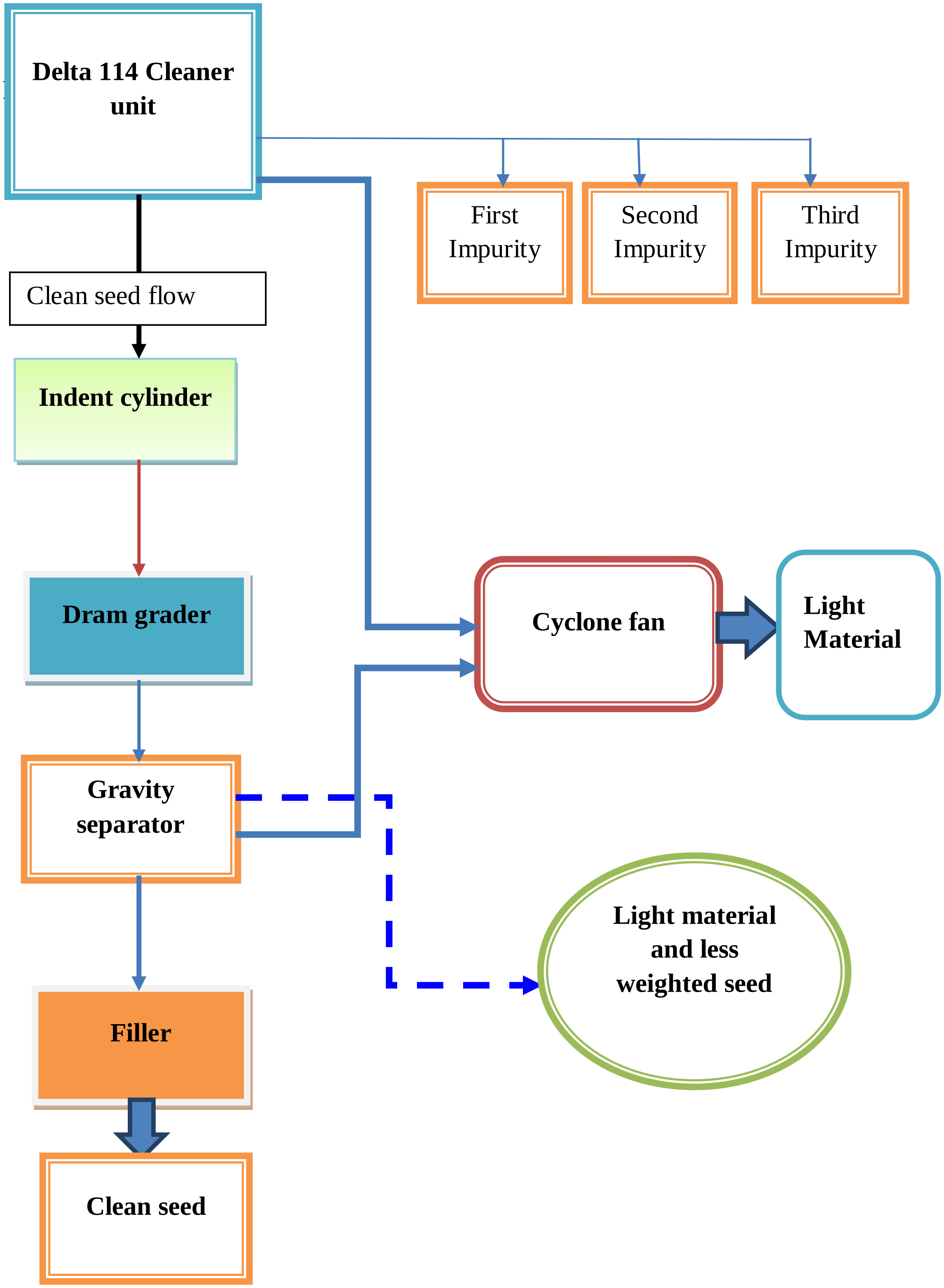

Figure 3.8. Clean seed and material other than seed exit flow chart

3.7. Performance Evaluation

3.7.1. Determination of feed rate (Fr)

Through put was taken as the mass of raw seed fed into the cleaner and the time taken to clean it. Equation 23 was used to determine the through put (Fr).

$$Fr = \frac{Q_t}{T} \text{---} (23)$$

Where, Q_t = total weight of raw seed fed into the cleaner, ton

T = time taken to clean sample, min

3.7.2. Determination of machine capacity (Mc)

Machine capacity is determined by ratio of input weight with time it takes to process seed. It given by equation (24)

$$Mc = \frac{\text{Input weigt}}{\text{Time taken}} \left(\frac{\text{ton}}{\text{hr}}\right) \text{---} (24)$$

3.7.3. Determination of total seed loss (TL)

Total seed Loss, TL is given by equation (25) as,

$$T_L = Csbc - Csac \text{---} (25)$$

Where, Csbc = mass of clean seed before cleaning (ton),

Csac = mass of clean seed after cleaning (ton)

3.7.4. Determination of seed recovery efficiency (Rey)

This is the percentage by weight of clean seed collected from grain outlet with respect to the total grain input. This is expressed in equation (26),

$$Rey = \frac{\text{Clean seed(Output)}}{\text{Raw seed(Input)}} \times 100\ \% \text{---} (26)$$

Where, Rey = Recovery efficiency in %

3.7.5. Determination of seed cleaning efficiency (CE)

This is the percentage by weight of clean seed with respect to all initial weight of clean seed. This is expressed in equation (27) as,

$$CE = \frac{w_s}{w_i} (\%) \text{---} (27)$$

Where, w_s = weight of clean seed at clean seed outlet, kg.

w_i = initial weight of clean seed, kg.

CE= Cleaning Efficiency (%).

3.7.6. Determination of cleaning loss (C_L)

Cleaning loss means ratio of total loss with weight of clean seed at clean seed outlet. It expressed in equation (28) as follow,

$$C_L = \frac{\text{Total Loss}}{\text{Weight of clean seed(output)}} \times 100\% \text{ -- (28)}$$

3.7.7. Determination of seed cleaner performance index (Oe orη_o)

This is a measure of the overall efficiency of the cleaner based on the cleaning efficiency and seed recovery efficiency. This is expressed in equation (29) as,

$$Oe = \frac{CE \times Rey}{100} \text{ --- (29)}$$

Where, Oe= Cleaning Efficiency in %

Rey = Recovery efficiency in %

3.8. Data collection method

The primary data was obtained from machine output when it clean different wheat seed called *Xamella, Adelle, garadela, heraro, hunte and sinina* at different time and at different feeding rate. Also the primary data used to evaluate performance of machine for barley was obtained machine output during it process the given amount of raw seed of different barley variety known as *garadela, xamela, sinana*. And the primary data used to evaluate performance of machine for bean was obtained machine output during it process the given amount of raw seed of different bean variety known as *sinana, Heraro and Adelle*. The secondary data was obtained from manufacturer manual and data bases.

3.9. Data analysis method

Data were analyzed according to the design of the experiment as recommended by Gomez and Gomez (1984). Analysis was made using SSPS software. The treatment means were compared with 5% levels of significance. Level of significance (P) for these relations was obtained by regression analysis based on analysis of variance. The figures are drawn by using ORIGIN and Excel software.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1. Determination of machine capacity

4.1.1. Determination of machine capacity of HD114

4.1.1.1. Machine capacity on wheat cleaning

As it shown in table (4.1) and Appendix table (1) the capacity of machine was increased dramatically with increment of feeding mass. But it decline between 0.32 ton and 0.44 ton mass inputs. The machine capacity was rise again after 0.44 ton mass inputs. As it shown in table 4.1 machine capacity rises from 0.05 ton.hr^{-1} to 0.08 ton.hr^{-1} when feeding increase from 0.2 ton to 0.32 ton. But it decline to 0.04 ton.hr^{-1} as feeding increased to 0.44 ton. And it rise again to 0.068 ton.hr^{-1} when input mass increase to 0.75 ton.

Table 4.1. HD114 seed clean machine capacity on wheat processing

Feeding(ton)	Output(ton)	Time(hr.)	Mc (ton.hr^{-1}.)
0.2	0.19	4	0.05
0.32	0.28	3.92	0.08
0.44	0.42	11	0.04
0.75	0.7	11	0.068

Where, Mc=Machine capacity.

Results showed that machine capacity was affected by feeding rate and quality of seed. The level of impurity also affects the capacity of machine. The statics analysis shows that p < (0.05) and the difference was significant.

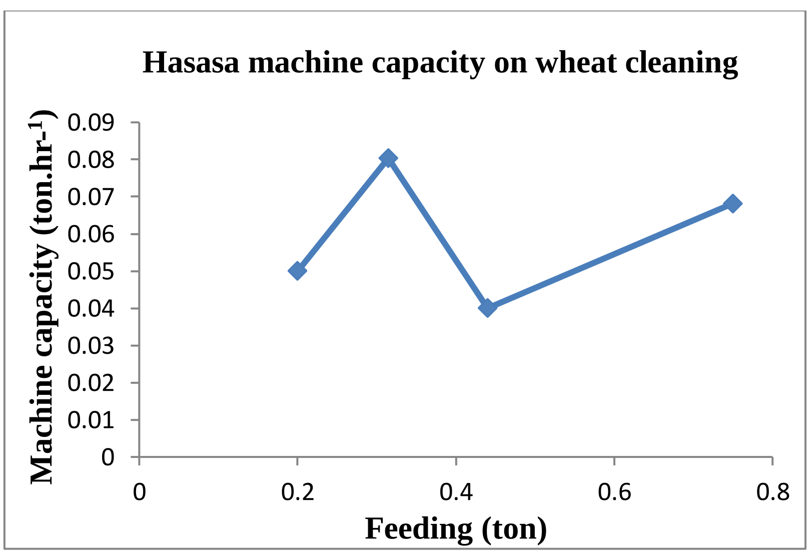

Figure 4.1. HD114 seed clean machine capacity on wheat processing

4.1.1.2. HD114 machine capacity on barley cleaning

The results of average overall Machine capacity HD114 are presented graphically in figures 4.2. Also, Table 4.2 through Table 2 in the Appendix contains the calculated values of machine capacity for different level of feeding and impurity level. As it shown the machine capacity increase at first with increment of feeding rate and it decline at middle point. As it shown in table 4.2 machine capacity rises from 0.024 $ton.hr^{-1}$ to 0.068 $ton.hr^{-1}$ when feeding increase from 0.098 ton to 0.23 ton. But it decline to 0.044 $ton.hr^{-1}$ as feeding mass increased to 0.480 ton. This show that machine capacity on barley is high when feeding in middle range feeding mass rate.

Table 4.2. HD114 machine capacity on Barley processing

Feeding(ton)	Output(ton)	Time(hr.)	Mc ($ton.hr^{-1}$)
0.098	0.091	4	0.024
0.23	0.19	3.5	0.068
0.48	0.47	11	0.044

Figure 4.2 show that the machine capacity increases continuously with increment of feeding but it decline after it addresses maximum capacity of machine can process barley effectively. The statisticals analysis shows at $p < (0.05)$ and the difference was significant.

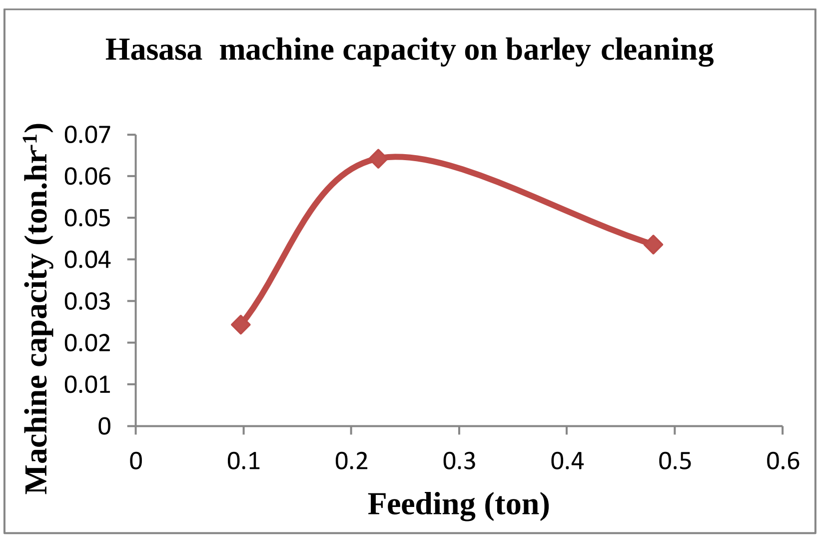

Figure 4.2. HD114 seed clean machine capacity on barley cleaning

4.1.1.3. HD114 Machine capacity on bean processing

Machine capacity tended to increase with increasing feeding rate while it addresses maximum point (Figure 4.3, Table 4.3). During bean processing HD114 seed cleaner capacity increase slightly with increment of feeding rate.

When we compare the capacity of machine when it process wheat with bean the machine able to process wheat than bean in large mass but the capacity of machine in bean processing is more stable. This caused by difference in physical properties between wheat and bean.

Table 4.3. HD114 seed cleaner capacity on bean cleaning

Feeding (ton)	Output (ton)	Time(ton)	Mc (ton.hr^{-1})
0.036	0.032	1	0.024
0.073	0.066	1.5	0.064
0.17	0.14	3	0.046

When feeding increase from 0.036 ton to 0.073 ton the machine capacity increase from 0.024 ton.hr^{-1} to 0.064 ton.hr^{-1}. But it decline to 0.046 ton.hr^{-1} as feeding mass was increased to 0.17 ton. The statisticals analysis shows that at $p < (0.05)$ and the difference was significant.

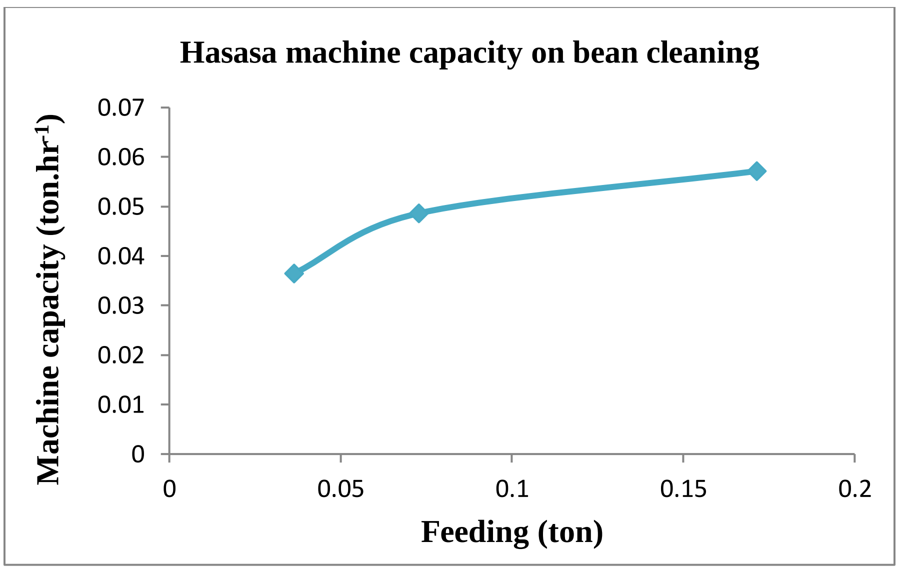

Figure 4.3. HD114 seed cleaner capacity on bean cleaning

4.1.2. DD114 cleaning machine on different seed type

4.1.2.1. DD 114 Machine capacity on wheat cleaning

As it shown in table (4.4) and Appendix table 5 the capacity of machine was increased dramatically with increment of feeding mass. It increases 0.036 ton.hr^{-1} to 0.055ton.hr^{-1} as input mass increase from 0.11 ton to 0.28 ton. But it decline between 0.28 ton and 0.36 ton feeding mass from 0.055 ton.hr^{-1} to 0.036 ton.hr^{-1} again. The machine capacity was increased again after 0.36 ton inputs up to 0.6 ton from 0.036 ton.hr^{-1} to 0.066 ton.hr^{-1}.

This indicates that the machine capacity of DD114 is high at low feeding rate and high feeding rate. But it is poor at middle feeding rate. This caused by Delta 114 cleaner machine was able to process wheat both at lower power efficiently with low feeding rate and it processed wheat with high power at higher feeding with constant capacity.

Table 4.4. DD114 cleaning machine capacity on wheat

Feeding (ton)	Output (ton)	Time (hr)	Mc ($ton.hr^{-1}$)
0.11	0.97	3	0.036
0.28	0.25	5	0.055
0.36	0.31	10	0.036
0.6	0.51	9	0.066

Results showed that machine capacity was less affected by feeding rate on wheat processing. The level of impurity also affects the capacity of machine by declining machine timeliness. As impurity rises, the machine capacity also declines.

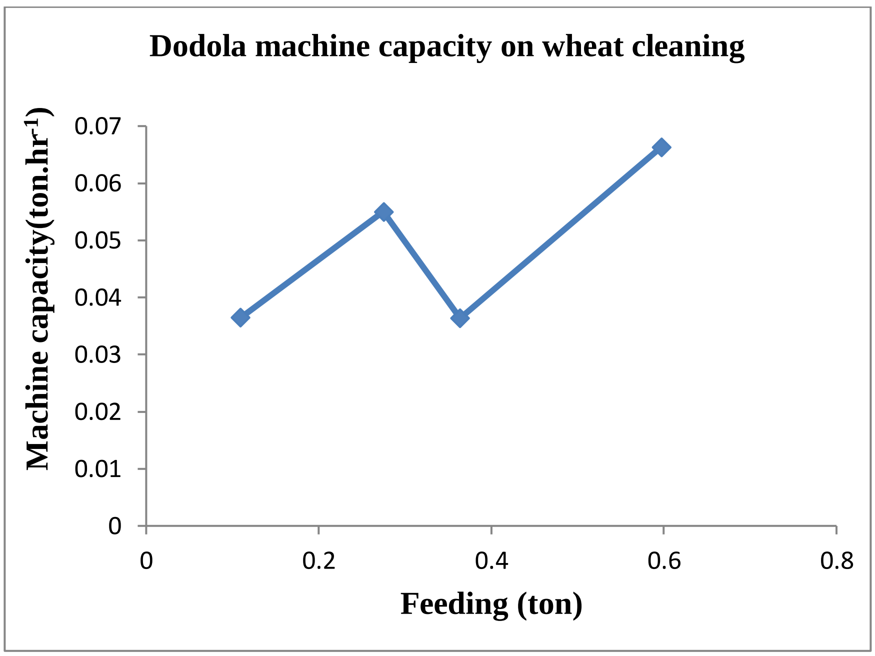

Figure 4.4. DD114 cleaning machine capacities on wheat

4.1.2.2. DD114 machine capacity on barley cleaning

The results of average overall Machine capacity DD114 are presented graphically in figures 4.5. Also, Table 4.5 and Table 6 in the Appendix contain the calculated values of machine capacity for different level of feeding mass. As it shown in tables and figures the machine capacity increase at first with increment of feeding rate and it decline at middle point. As it shown in table 4.5 machine capacity rises from 0.04 $ton.hr^{-1}$ to 0.051 $ton.hr^{-1}$ when feeding increase from 0.04 ton to 0.2 ton.

But it was decreased to 0.049 $ton.hr^{-1}$ as feeding increased to 0.5 ton. This show that machine capacity on barley is high when feeding mass in average between maximum and minimum value of feeding rate.

Table 4.5. DD114 machine capacity on barley processing

Feeding (ton)	Output (ton)	Time (hr)	Mc($ton.hr^{-1}$)
0.04	0.33	1	0.04
0.21	0.16	4	0.051
0.5	0.42	10	0.049

Figure 4.2b show that the machine capacity increases continuously with increment of feeding but it decline after it addresses maximum capacity of machine can process barley effectively. But DD114 able to process barley with stable capacity as it seen from figure follow. Clearly it described that machine capacity less affected by feeding rate on when barley processing and it show more stability. As impurity rises the machine capacity decline in some extent on barley processing too. The statisticals analysis shows that at $p < (0.05)$ and the difference was significant.

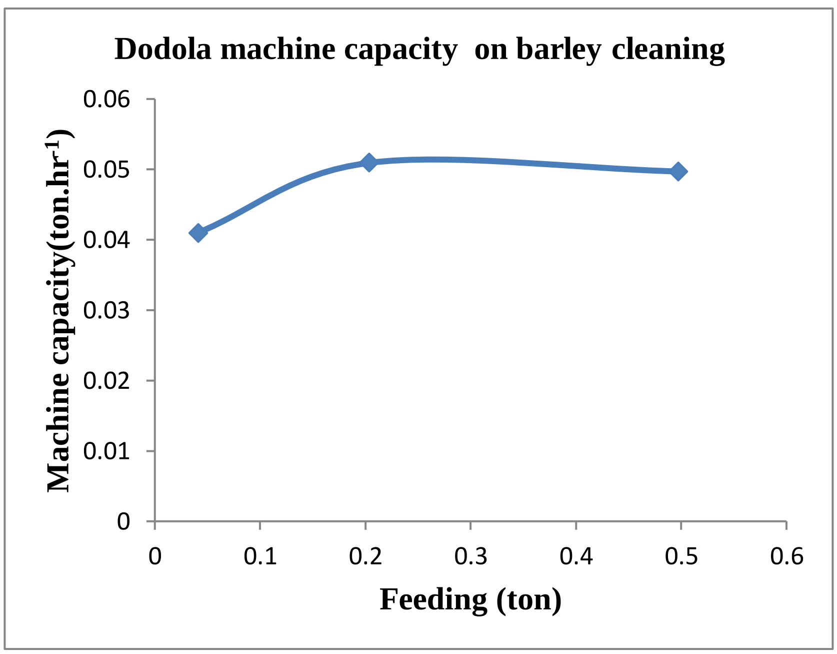

Figure 4.5. DD114 machine capacities on barley cleaning

4.1.2.3. DD114 Machine capacity on bean processing

Machine capacity tended to increase with increasing feeding rate while it addresses maximum point it can be process bean seed efficiently (Figure 4.6, Table 4.6 and appendix table 4).

During bean processing DD114 seed cleaner capacity increase slightly with increment of feeding rate and decline after the seed cleaner get it is maximum inflation point it can process effectively.

Table 4.6. DD114 machine capacity on bean processing

Feeding (ton)	Output (ton)	Time (hr)	Mc ($ton.hr^{-1}$)
0.02	0.04	2	0.009
0.13	0.10	5	0.026
0.18	0.12	10	0.017

When feeding mass increase from 0.02 ton to 0.13 ton the machine capacity increase from 0.009 $ton.hr^{-1}$ to 0.026 $ton.hr^{-1}$. But it decline to 0.017 $ton.hr^{-1}$ when feeding mass decrease to 0.18 ton. The decline of machine capacity coming from the thickness of seed sample on screen during bean process and it is difficult to clean light material for bean by aerodynamic system. It takes long duration of time to clean bean as feeding mass increases. As impurity rises, the machine capacity also declines.

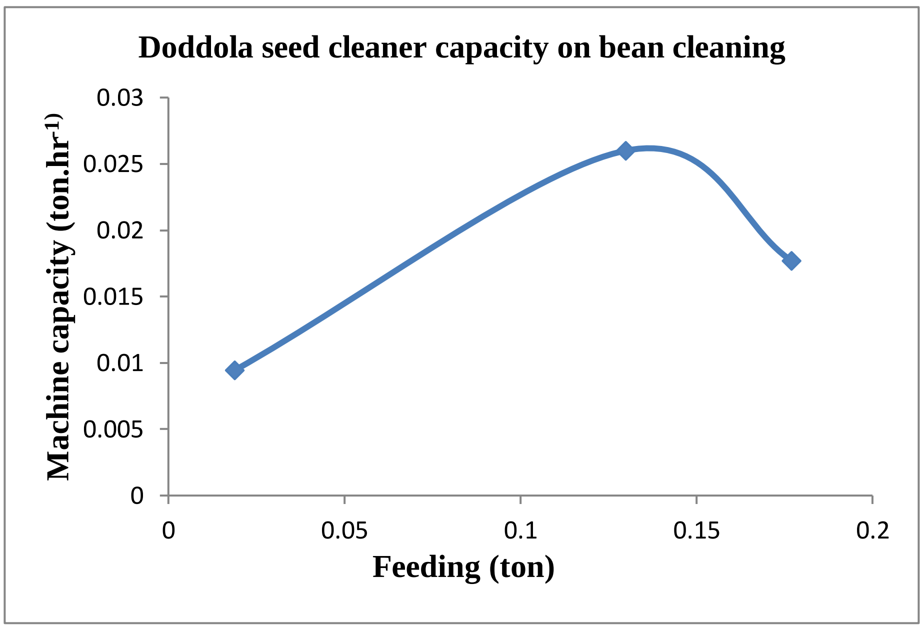

Figure 4.6. DD114 machine capacity (Mc) on bean processing

4.2. Comparison of HD114 and DD114 seed cleaners

4.2.1. Comparison HD114 and DD114 machine capacities on wheat cleaning

As it shown in figure (4.7) and Appendix table (1, 2) HD114 cleaner machine capacity was 0.062 $ton.hr^{-1}$ in average. The DD114 machine capacity was 0.042 $ton.hr^{-1}$ in average. In general the HD114 machines capacities is high in cleaning and grading wheat.

The average machine capacities of two Delta's 114 for wheat cleaning and grading were found to be in the following order:

HD114 > DD114

The ranges of machine capacities were from 0.05 ton.hr^{-1} to 0.0079 ton.hr^{-1} for HD114 and from 0.037 ton.hr^{-1} to 0.0648 ton.hr^{-1} for DD114. This implies that HD114 perform well under different level of impurity and feeding rate in stable state without high loss.

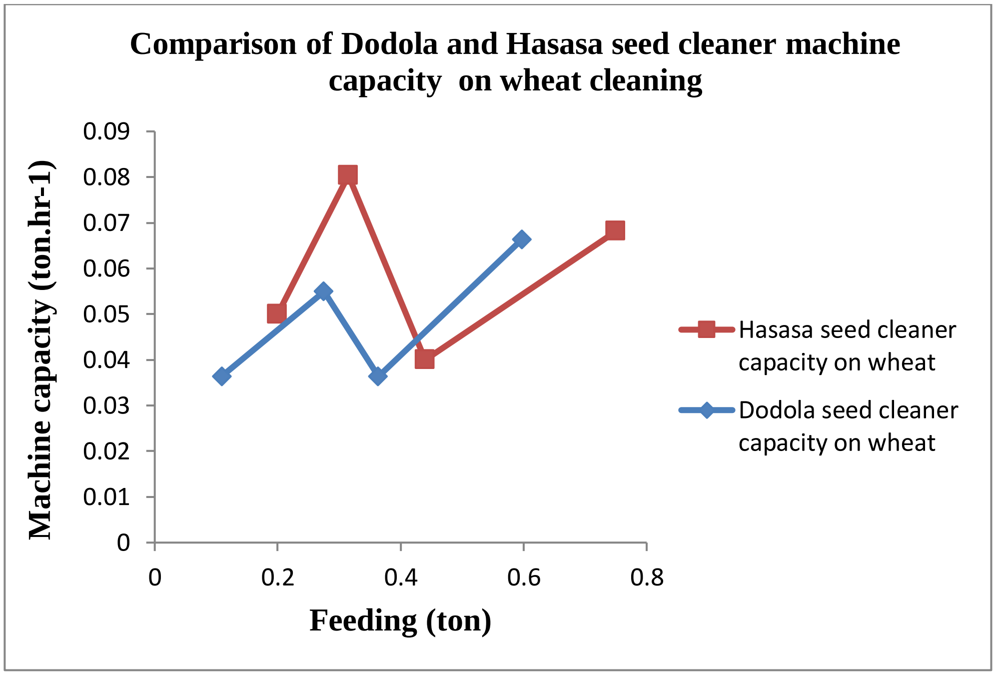

Figure 4.7. DD114 and HD114 seed cleaner capacity comparisons on wheat.

4.2.2. Comparisons of HD114 and DD114 machine capacities on barley cleaning.

The results of average machine capacities are presented graphically in Figures 4.8. Also, Appendix table (2, 5) in the Appendix contain the calculated values of machine capacities for the different types feed rate and impurity level. The average machine capacities of the two Delta's 114 for barley were found to be in the following order:

DD114 > HD114

The ranges of average overall efficiencies were from 0.041 ton.hr^{-1} to 0.065 ton.hr^{-1} for DD114 and from 0.025 ton.hr^{-1} to 0.05 ton.hr^{-1} for HD114 ton.hr^{-1}. As it shown on figure 4.8, DD114 seed cleaner did it maximum performance under vary seed rate and level of impurity without losing its ability and capacity with stable performance. But HD114 capability decline after it perform it critical point. This makes DD114 more capable on Barley processing.

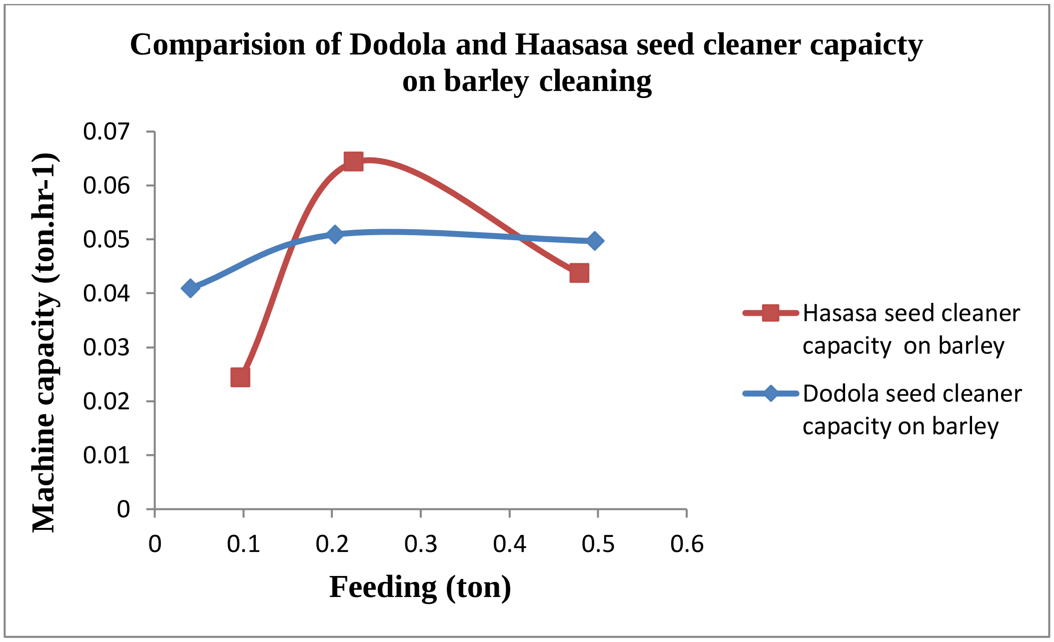

Figure 4.8. Comparisons of HD114 and DD114 machine capacities on barley.

4.2.3. Comparisons of DD114 and HD114 seed cleaner capacity on bean cleaning

The results of average machine capacities are presented graphically in Figures 4.9. Also, Appendix table (3, 4) in the Appendix contain the calculated values of machine capacities for the different types feed rate and impurity level for both machine on bean. The average machine capacities of the two Delta's 114 for bean were found to be in the following order:

HD114 > DD114

The ranges of average overall efficiencies were from 0.036 ton.hr^{-1} to 0.054 ton.hr^{-1} for HD114 and from 0.0094 ton.hr^{-1} to 0.017 Ton.hr^{-1} for DD114 Ton.hr^{-1}. As it described on figure 4.9 DD114 perform bean processing oppression with stead performance at vary feed rate and impurity. But HD114 capacity to process bean went in higher capacity. This implies that HD114 can perform higher during bean processing when it was compared with DD114.

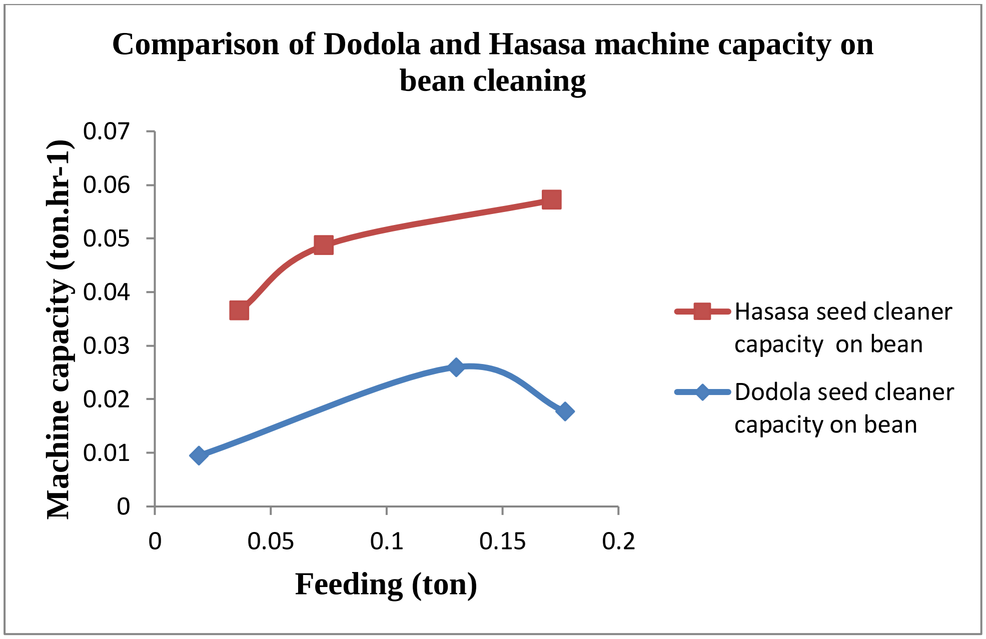

Figure 4.9. The comparisons of DD114 and HD114 seed cleaner capacity on bean

4.3. Determination of feed mass in time with different cleaning efficiency and loss

Inverse relationships had been recorded between machine capacity and cleaning efficiencies with feed rate. The inverse relationship between cleaning efficiency and feed rate was indicated be due to the increasing load on the sieve that restricted free movement of seeds and undesired materials. As example for HD14 CE for wheat decline from 98.45% to 95.8% when feeding mass increase from 200 ton to 750 ton, for barley it decline from 95.65 to 89.82% as feeding mass increase from 97.5 to 480 ton and for bean it decline from 83.33 to 77.83% as feeding mass increase from 36.5 to 171.5 ton. Also for DD114 for wheat, it decline from 99.80 to 90.5% as feeding was increased from 109.3 to 597 ton, for barley 97.01 to 93.13% as cleaning was increased from 41 to 487 ton and 85.89 to 78.76% as feeding was increased from 18.9 to 177 ton. See appendix (table 7 - table 12).

When we compare feed rate of each machine with different seed variety HD114 owned maximum feed rate 1.03 ton.hr^{-1} in average for wheat and DD114 contain 0.79 ton.hr^{-1} feed rate in average for bean. This means machines able to feed maximum ton of seed in short period of time more than any other seed variety. DD114 was able to feed barley in good manner more than HD114 as it shown in figure 4.10. As it shown in figure 4.10 too DD114 had lowest feed rate on bean processing.

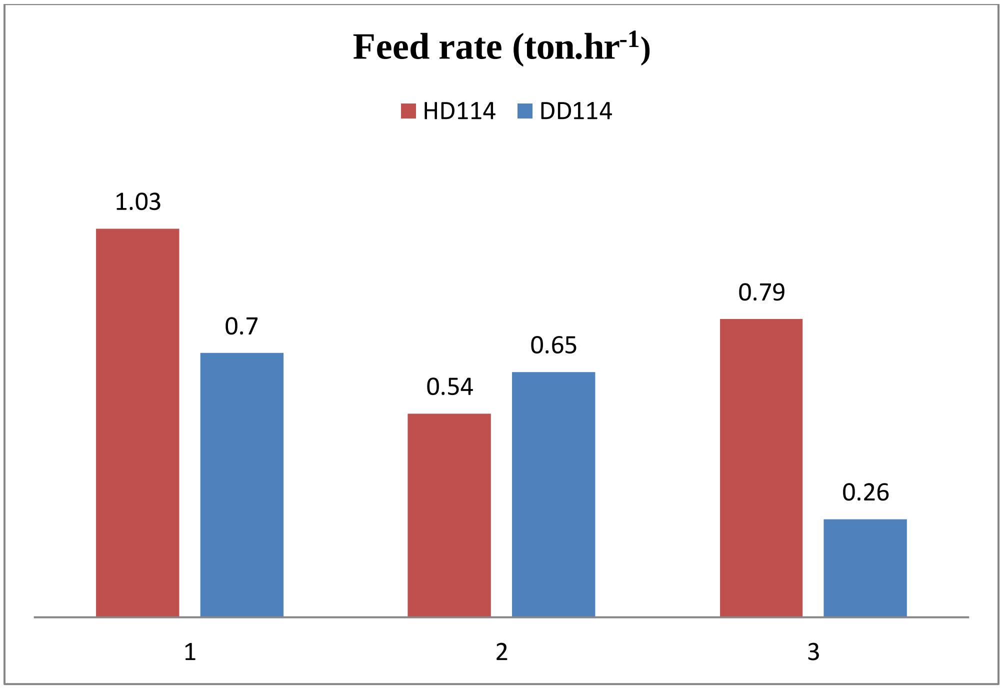

Figure 4.10. average feed rates for different seed varieties; where 1 stands for wheat, 2 for barley and 3 for bean % of cleaning efficiency.

4.4. Determination of cleaning efficiency and cleaning loss

4.4.1. HD114 cleaning efficiency and cleaning loss

4.4.1.1. HD114 cleaning efficiency and cleaning loss for wheat cleaning

As can be seen from Appendix Table 7 and table 4.7, when the feeding mass was increased from 200ton to 750 Ton cleaning efficiency decreased from 98.45 to 95.80%. At that time, the cleaning loss was increased from 1.57 to 4.93%. Figure 4.11 shows the relationship between cleaning efficiency, cleaning loss and feeding mass. The declining cleaning efficiency and increasing cleaning loss with increasing rate of feeding was due to the formation of a thick layer of material on sieves that considerably hindered or limited passage of seeds through the sieve perforations. The increasing in cleaning loss and decreasing of cleaning efficiency with increasing feeding mass could be attributed to the load intensity on the sieve that could result in obstruction of the sieve with material other than seed blocking sieve holes.

Table 4.7. HD 114 CE and CL for wheat

Feeding (ton)	Output (ton)	First impurity (ton)	Second impurity (ton)	Third impurity (ton)	Debris (ton)	Loss (ton)	Cleaning efficiency (%)	Cleaning loss (%)
200	190.5	3.3	0	1.2	2	3	98.45	1.57
315	278.5	11.65	6.4	3.6	5.65	9.2	96.80	3.30
440	415	6.9	0	3	1.3	13.8	96.78	3.33
750	700	18.5	0	0	0.8	30.7	95.80	4.39

The average of cleaning efficiency and cleaning loss of HD114 was done. As it recorded in Appendix table 7 the average value for 20 different inputs was 96.8% for wheat in cleaning efficiency and 3.24% was recorded in cleaning loss for during wheat cleaning and grading by HD114. This signifies that HD114 has maximum performance in wheat cleaning and grading with minimum loss. The cleaning efficiency of HD114 affected less by the increment of feeding mass as it shown in tables and figure.

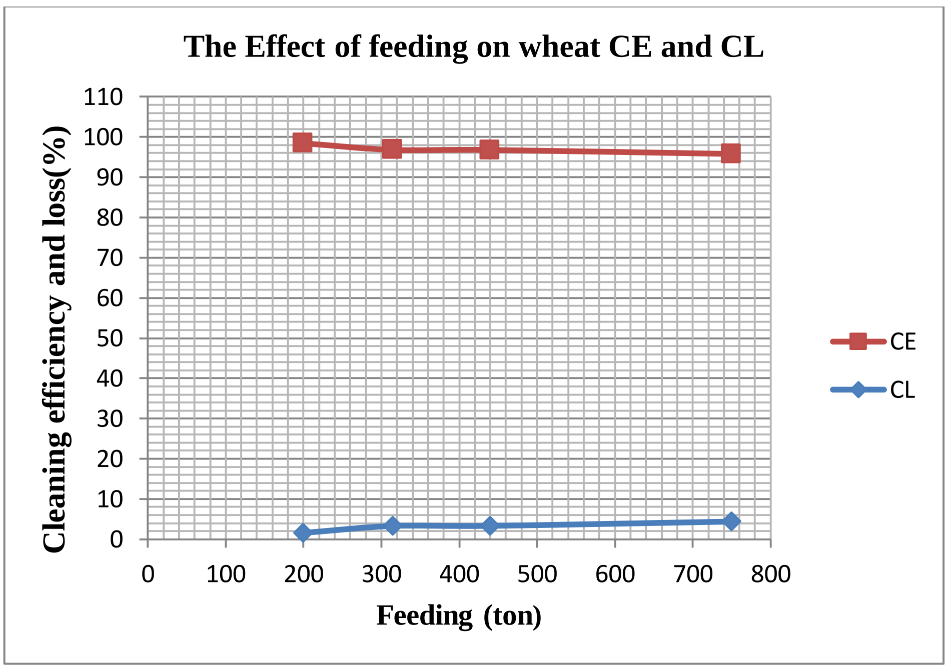

Figure 4.11. HD 114 CE and CL for wheat

4.4.1.2. HD114 cleaning efficiency and cleaning loss for barley cleaning

As can be seen from Appendix Table 8 and table 4.8, when the feeding mass was increased from 97.5 ton to 480 Ton cleaning efficiency decreased from 95.65 to 89.82%. At that time, the cleaning loss was increased from 4.55 to 11.33%. Figure 4.12 shows the relationship between cleaning efficiency, cleaning loss and feeding mass.

The reason behind decline of cleaning efficiency and increment of loss is the same as wheat cleaning process as it mentioned above.

Table 4.8. HD 114 CE and CL for Barley

Feeding (ton)	Output (ton)	First Impurity (ton)	Second Impurity (ton)	Third impurity (ton)	Debris (ton)	Loss (ton)	Cleaning efficiency (%)	Cleaning loss (%)
97.5	90.625	0	1.75	0	1	4.125	95.65	4.55
225	150.75	23	20	18.25	2.8	10.2	93.66	6.77
480	403.25	12.6	6	9.6	2.85	45.7	89.82	11.33

The average of cleaning efficiency and cleaning loss of HD114 for barley was done. As it recorded in Appendix table 8 the average value for 21 different inputs was 92.99% for barley in cleaning efficiency and 7.56 percent was recorded in cleaning loss for Barley during all cleaning and grading recorded time by HD114. This signifies that HD114 has high performance in barley cleaning and grading with middle loss when it compare with HD114 performance with wheat processing by it. The cleaning efficiency of HD114 was affected more by the increment of feeding mass as when it was compared with wheat as it indicated on table 4.8 and figure 4.12.

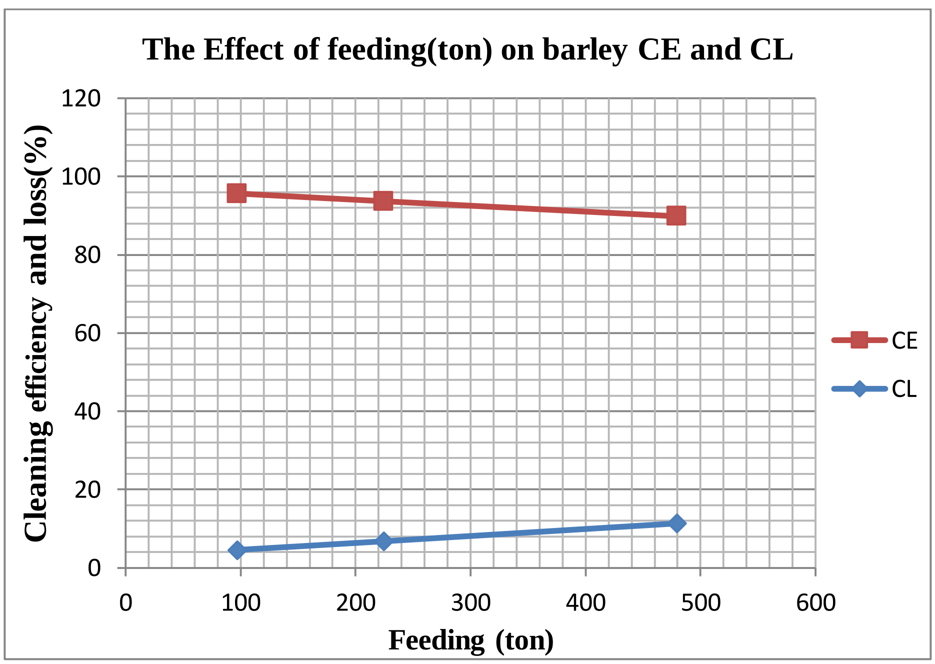

Figure 4.12. HD114 CE and CL for Barley

4.4.1.3. HD114 cleaning efficiency and cleaning loss for bean

Figure4.13 and Appendix table 9 indicate that cleaning efficiency decreased with increasing feeding mass while the cleaning loss increased with increasing feeding mass. Increasing feeding mass from 36.5 ton to 171.5 ton decreased the cleaning efficiency from 83.33 to 77.83% while cleaning loss increased from 20 to 28.48 %.

The low cleaning efficiency and the high cleaning loss with the increasing feeding mass could be due to the thick layer of material (matting of grains and chaff) formed on the sieves that constrained penetration of grain through the mat of materials on the sieves and; hence, effect of the feeding mass could be seen as increasing of the thickness of mixture of seed and chaff layer on sieve.

Table 4.9. HD114 CE and CL for Bean

Feeding (ton)	Output (ton)	First impurity (ton)	Second impurity (ton)	Third impurity (Ton)	Debris (Ton)	Loss (Ton)	Cleaning efficiency (%)	Cleaning loss (%)
36.5	25	3.55	0	0.8	2.15	5	83.33	20
73	48.5	7.4	2.98	1.2	0.4	12.52	79.48	25.81
171.5	115	9.5	8.27	5.18	0.8	32.75	77.83	28.48

The average of cleaning efficiency and cleaning loss of HD114 for bean was done. As it recorded in Appendix table (9) the average value for 3 different inputs was 80.22% for bean in cleaning efficiency and 24.77% was recorded in cleaning loss for bean during all cleaning and grading recorded time by HD114. This signifies that HD114 has medium performance in bean cleaning and grading with high loss when it was compared with HD114 performance with wheat processing by the machine itself.

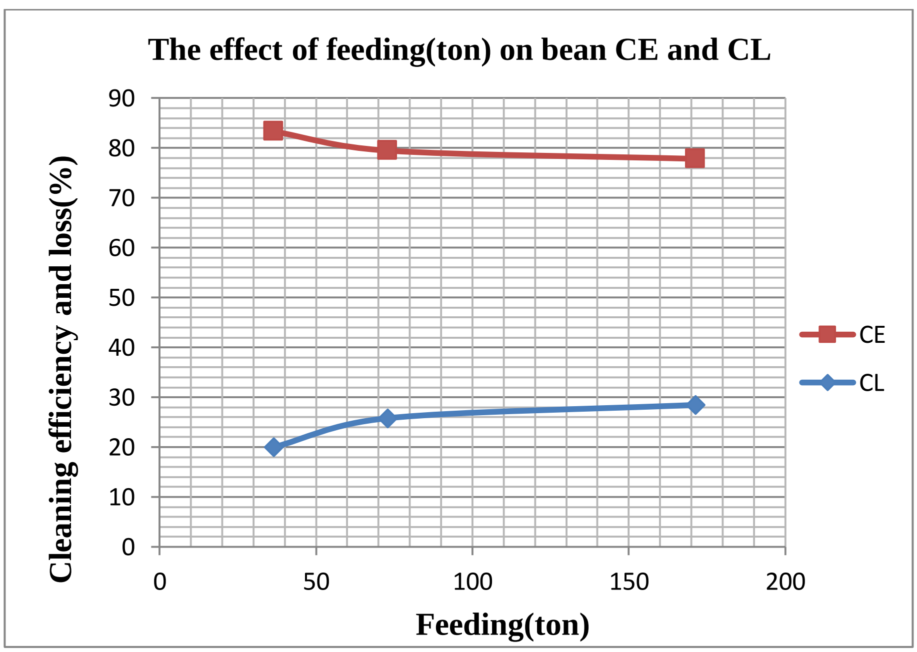

Figure 4.13. HD114 CE and CL for Barley.

4.4.2. Determination of DD114 cleaning efficiency and cleaning loss

4.4.2.1. DD114 cleaning efficiency and cleaning loss for wheat

As can be seen from Appendix Table 10 and table 4.10, when the feeding mass was increased from 109.3ton to 597 Ton cleaning efficiency decreased from 99.80 to 90.57%. At that time, the cleaning loss was increased from 0.2 to 10.4%. Figure 4.14 shows the relationship between cleaning efficiency, cleaning loss and feeding mass. The declining cleaning efficiency and increasing cleaning loss with increasing feeding mass was due to the formation of a thick layer of material on sieves that considerably hindered or limited passage of seeds through the sieve perforations.

Table 4.10 DD114 CE and CL for wheat

Feeding (ton)	Output (ton)	First impurity (ton)	Second impurity (ton)	Third impurity (ton)	Debris (ton)	Loss (ton)	Cleaning efficiency (%)	Cleaning loss (%)
109.3	97.5	6.4	4.8	0	0.4	0.2	99.80	0.2
275	245	18.6	0	3.5	3	4.9	98.04	2.0
363.6	293	30.3	18.4	4	3.2	14.7	95.22	5.0
597	506	16.1	15.2	3	4	52.7	90.57	10.4

As it recorded in Appendix table 10, the mean value for 27 different inputs was 95.5% for wheat in cleaning efficiency and 4.8% was recorded in cleaning loss during wheat cleaning and grading by DD114. The wheat processing cleaning efficiency of DD114 affected less by the increment of feeding mass as it indicated in tables 4.10 and figure 4.14.

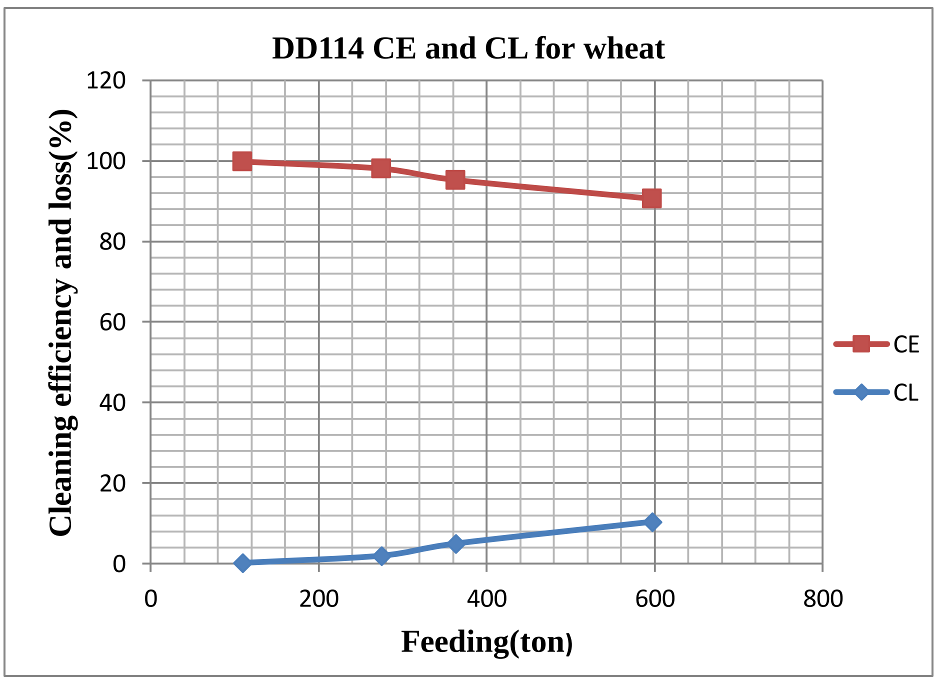

Figure 4.14. DD114 CE and CL for wheat cleaning

4.4.2.2. DD114 cleaning efficiency and cleaning loss for barley

As can be seen from Appendix Table 11 and table 4.11, when the feeding mass was increased from 41 to 497 ton cleaning efficiency declined from 97.01 to 93.13%. At that time, the cleaning loss was increased from 3.08 to 7.38%. Figure 4.15 shows the relationship between cleaning efficiency, cleaning loss and feeding mass.

Table 4.11. DD114 CE and CL for barley

Feeding (ton)	Out put (ton)	First impurity (ton)	Second impurity (ton)	Third impurity (ton)	Debris (ton)	Loss (ton)	Cleaning efficiency (%)	Cleaning Loss (%)
41	32.5	4.2	0	2.5	0.8	1	97.01	3.08
203.7	164	18.1	0	11	4.8	5.8	96.58	3.54
497	416	25	0	21	4.3	30.7	93.13	7.38

As it recorded in Appendix table 11 the mean value for 19 different inputs was 95.65% for barley in cleaning efficiency and 4.57% was recorded in cleaning loss for Barley during all cleaning and grading recorded time by DD114. This signifies that DD114 has high performance in barley cleaning and grading with middle loss when it compare with DD114 performance on barley even its own performance for wheat. The cleaning efficiency of DD114 for barley affected approximately the same by the increment of feeding mass when it compare with performance on wheat as it shown in tables and figure.

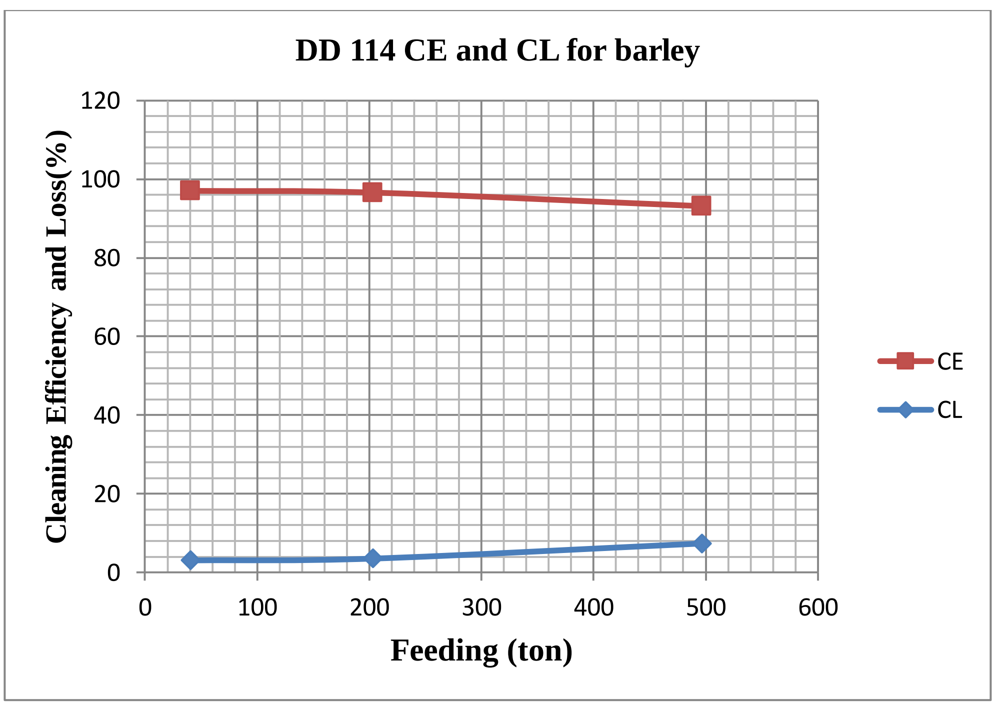

Figure 4.15. DD114 CE and CL for bean cleaning

4.4.2.3. DD114 cleaning efficiency and cleaning loss for bean cleaning

Figure 4.16 and Appendix Table 12 indicate that cleaning efficiency decreased with increasing feeding mass while the cleaning loss increased with increasing feeding mass. Increasing feeding mass from 18.9 ton to 177 ton decreased the cleaning efficiency from 85.89 to 78.76 % while cleaning loss increased from 16.43 to 26.96 %. s. The statisticals analysis shows at $p < (0.05)$ and the difference was significant. The R squared value for three types of them was greater than 0.95.

Table 4.12 DD114 CE and CL for bean

Feeding (ton)	Output (ton)	First impurity (ton)	Second impurity (ton)	Third impurity (ton)	Debris (ton)	Loss (ton)	Cleaning efficiency (%)	Cleaning Loss (%)
18.9	14	2	0	0	0.6	2.3	85.89	16.43
130	82.2	18	0	0	10	19.8	80.59	24.09
177	102	38.5	0	4.7	4.3	27.5	78.76	26.96

As it recorded in Appendix table (12) the mean value for 9 different inputs was 80.99% for bean in cleaning efficiency and 23.4% was recorded in cleaning loss for bean during all cleaning and grading recorded time by DD114. The cleaning efficiency of DD114 was affected severely by the increment of feeding mass on bean when it was compared with barley and wheat as it shown in tables 4.12s and figures 4.16s.

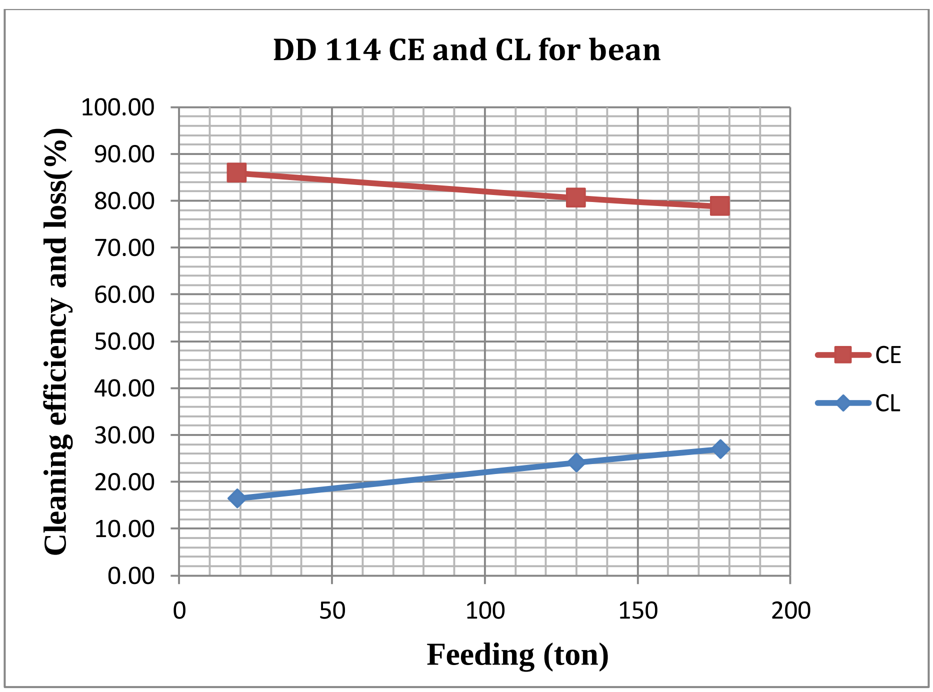

Figure 4.16. DD114 CE and CL for bean cleaning

4.5. Performances evaluation

Analyses of various factors for performance of the two seed cleaning machine HD114 and D114 were compared with results of each other. The results of average cleaning efficiencies, cleaning loss, seed recovery and overall efficiency are presented graphically in Figures 4.17, figure 4.18, figure 4.19 and figure 4.20. Also, Appendix table 13 contain the calculated values of cleaning efficiencies, cleaning loss, seed recovery and overall efficiency for the three variety of seeds for the HD114 and DD114 of cleaning machines. The average cleaning efficiency, seed recovery and average overall efficiency of the two machines for wheat and bean was found to be in the following order:

HD114 > DD114

But average cleaning efficiency, seed recovery and average overall efficiency of DD114 is higher than HD114 for barley. The statistical analysis showed that the difference between the two machines was significant. The average cleaning loss of each machine for wheat was found to be in the following order:

HD114 < DD114

But cleaning loss of HD114 is higher than DD114 for barley. It should be noted that the impurity for seeds samples are defined as oversized, large size impurity, leaf, broken steam and big seed, which could be separated by the scalper was collected, measured and recorded. Most of the materials such as debris and small size impurity were separated by blower were weighted as debris. The general comparisons on cleaning efficiencies, cleaning loss, seed recovery and overall efficiency were discussed as follow,

4.5.1. Comparisons of cleaning efficiency for HD114 and DD114 seed cleaners

The ranges and average values of cleaning efficiencies are summarized in appendix table 13 and figure 4.16. The ranges of average values for the three seeds evaluated were from 80.22% to 96.89% for the HD144 and from 80.99% to 95.5% for the DD114. The statistical analysis (Table 4.13) showed that the means of cleaning efficiency for each of the three seeds evaluated were significantly different each other. The results showed that no model evaluated is applicable for all three crops. However, as shown in appendix table 13, the HD114 had the highest cleaning efficiencies for wheat. Both HD114 and DD114 had a near performance cleaning efficiency for beans; the lowest efficiency of HD114 on barley when it compared with DD114.

The highest efficiency of the DD114 was 95.65% for barleys; the lowest efficiency was 80.99% for bean. The average cleaning loss of each machine was found to be in the following order:

CE for wheat: DD114 < HD114

CE for barley: HD114 < DD114

CE for bean: HD114 ≅ DD114

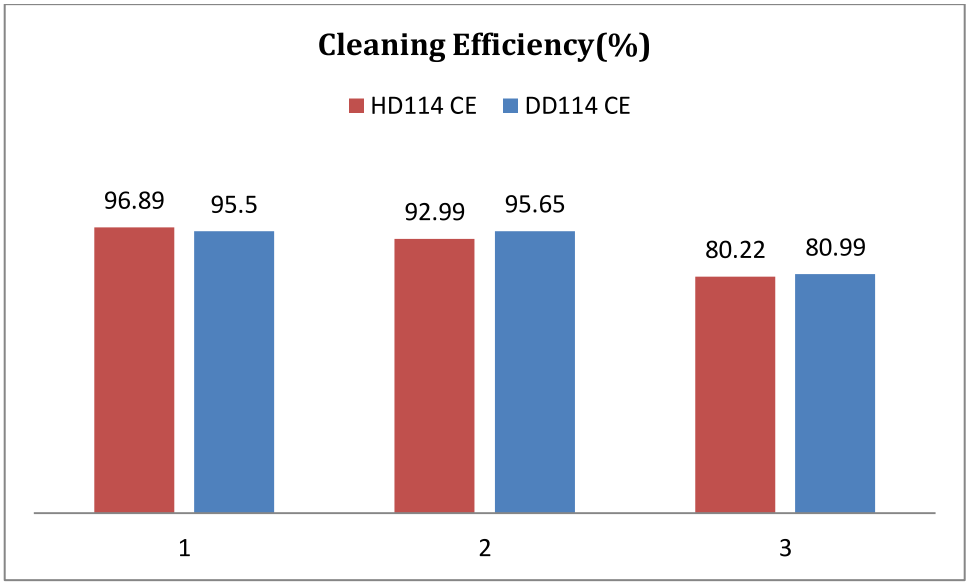

Figure 4.17. Comparisons of Cleaning Efficiency for HD114 and DD114

(1 stand for wheat, 2 for barley and 3 for bean Overall efficiency)

4.5.2. Comparisons of cleaning loss for HD114 and DD114 seed cleaners

The results of average cleaning loss are presented graphically in Figures 4.18. Also, Appendix table 13 contains the calculated values of cleaning loss for the three seed verities to evaluate machines performance. The ranges of average values for the three crops evaluated were from 3.22% to 24.76% for the HD144 and from 4.8% to 23.54% for the DD114. The statistical analysis (table 4.13) showed that the means of cleaning loss for each of the three seeds evaluated were significantly different each other. The results showed that no model evaluated is applicable for all three crops. However, as shown in appendix table 13, the DD114 had the highest cleaning loss for wheat. It had a near level of cleaning loss for beans; the lowest loss on barley when it compared with HD114. The highest loss of the HD114 was 24.76% for beans; the lowest loss was 3.22% for wheat. The average cleaning loss of each machine was found to be in the following order:

CL for wheat: DD114 > HD114

CL for barley: HD114 > DD114

CL for bean: HD114 ≥ DD114

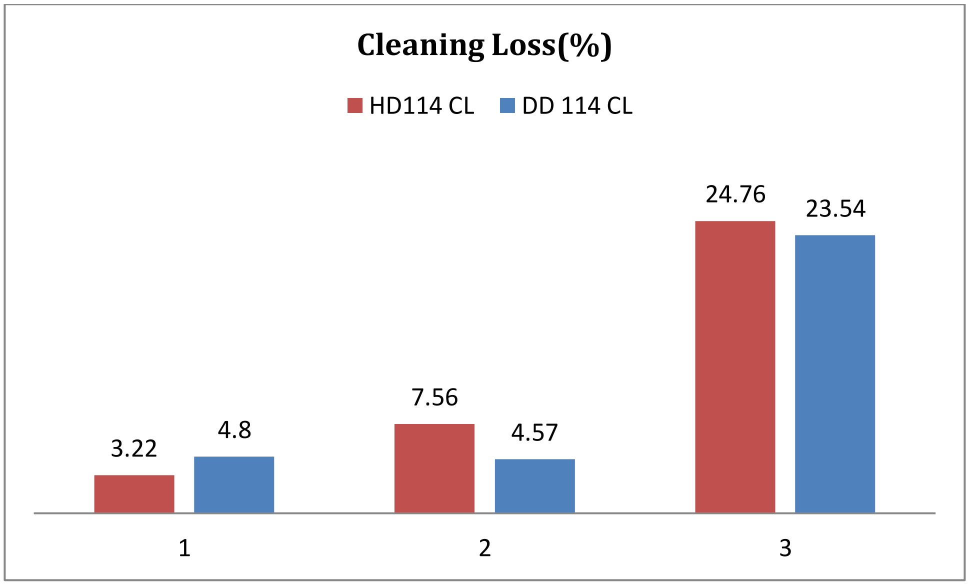

Figure 4.18. Comparisons of Cleaning Loss for HD114 and DD114
(1 stand for wheat, 2 for barley and 3 for bean Overall efficiency)

4.5.3. Comparisons of seed recovery for HD114 and DD114 cleaner

The results of average seed recovery are presented graphically in Figures 4.19. Also, Appendix table 13 contains the calculated values of seed recovery for the three seed verities to evaluate machines performance. The ranges of average values for the three seed crops evaluated were from 91.43% to 92.6% for the HD144 and from 61.44% to 84.83% for the DD114. The statistical analysis (table 4.13) showed that the means of cleaning loss for each of the three seeds evaluated were significantly different each other.

The results showed that no model evaluated is applicable for all three crops. However, as shown in appendix table 13, the HD114 had the highest seed recovery for wheat and bean. It had a less or near to equal seed recovery for barley; the seed recovery on bean when it compared with DD114. The highest seed recovery of the HD114 was 92.6%% for wheat; the lowest seed recovery was 83.76% for barley. The average seed recovery of each machine was found to be in the following order:

Rey (%) for wheat: HD114 > DD114

Rey (%) for barley: DD114 ≥ HD114

Rey (%) for bean: HD114 > DD114

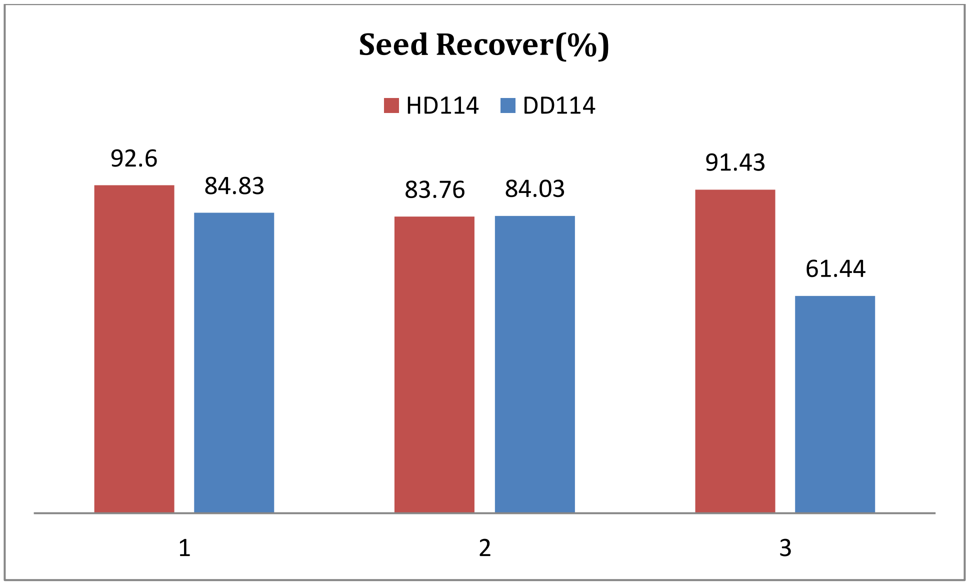

Figure 4.19. comparisons of seed recovery for HD114 and DD114
(1 stand for wheat, 2 for barley and 3 for bean Overall efficiency)

4.5.4. Comparisons of overall efficiency

The results of average overall efficiency are presented graphically in Figures 4.20. Also, Appendix table 13 contains the calculated values of overall efficiency for the three seed verities to evaluate machines performance. The ranges of average values for the three crops evaluated were from 72.27% to 89.75% for the HD144 and from 49.86% to 81.03% for the DD114. The statistical analysis (table 4.13) showed that the means of overall efficiency for each of the three seeds evaluated were significantly different each other. The results showed that no model evaluated is applicable for all three crops. However, as shown in appendix table 13, the HD114 had the highest overall efficiency for wheat.

It had a less overall efficiency for barley; the overall efficiency on bean but more than DD114 overall efficiency on bean when it compared with DD114. The highest overall efficiency of the DD114 was 81.03% for wheat; the lowest overall efficiency was 49.86% for bean. The average overall efficiency of each machine was found to be in the following order:

Overall efficiency for wheat: HD114 > DD114

Overall efficiency for barley: HD114 < DD114

Overall efficiency for bean: HD114 ≥ DD114

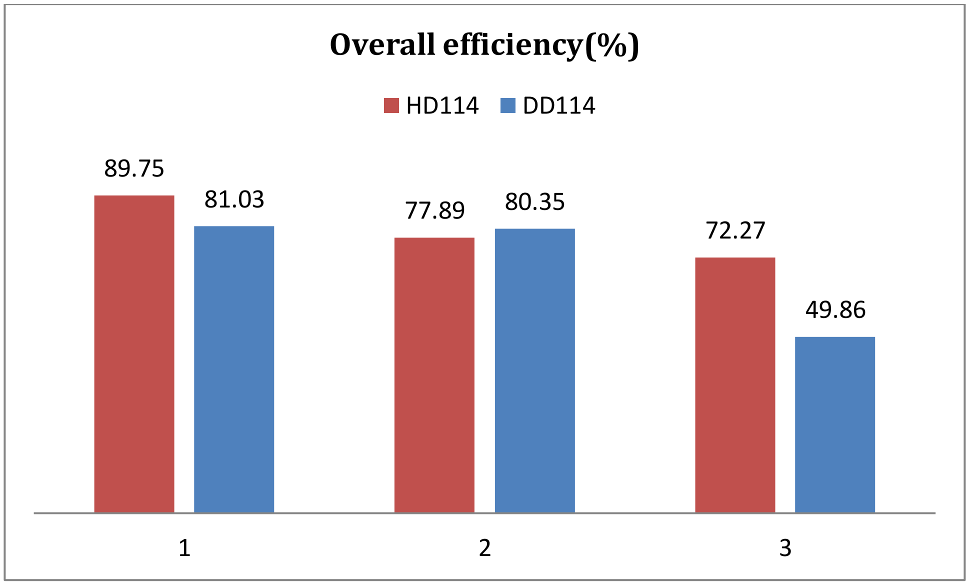

Figure 4.20. Comparisons of Overall efficiency for HD114 and DD114

(1 stand for wheat, 2 for barley and 3 for bean Overall efficiency)

4.6. Statistical analysis

Table 4.13 Means ± Standard Deviation and Range for cleaning and overall efficiency, cleaning loss, seed recovery and feed rate corresponding to each machine

Parameters	Seed cleaners	Wheat	Barley	Bean
Cleaning efficiency (%)	HD114	96.89 ± 0.82	92.99 ± 1.45	80.22 ± 3.16
	DD114	95.50 ± 2.65	95.65 ± 1.46	80.99 ± 1.62
Cleaning Loss (%)	HD114	3.22 ± 0.88	7.56 ± 1.68	24.76 ± 4.82
	DD114	4.8 ± 2.94	4.57 ± 1.62	23.54 ± 3.26
Seed Recovery (Rey, %)	HD114	92.6 ± 3.14	83.76 ± 6.43	91.43 ± 3.83
	DD114	84.83 ± 4.07	84.03 ± 3.4	61.44 ± 7.12
Overall efficiency (%)	HD114	89.75 ± 3.25	77.89 ± 5.94	72.27 ± 1.02
	DD114	84.83 ± 4.75	84.03 ± 2.76	61.44 ± 7.1
Feed Rate (Fr, Ton.hr^{-1})	HD114	1.03 ± 0.22	0.54 ± 0.014	0.79 ± 0.2
	DD114	0.7 ± 0.014	0.65 ± 0.014	0.26 ± 0.1

The multiple regression analysis made the level correlation coefficients were used to identify parameters that had a dominant effect on separation and cleaning efficiencies and associated losses.

Table 4.14 multiple regression equation of parameters studied.

Regression	**Equation**	R^2
Mc vs Input vs time of HD114 on wheat	Mc = 91.579 – 0.01In + 0.02t	0.33
Mc vs Input vs time of HD114 on Barley	Mc = 0.013 + 0.74In – 0.91t	1
Mc vs Input vs time of HD114 on Bean	Mc = 0.029 + 0.05In -0.13t	1
Mc vs Input vs time of HD114 on wheat	Mc = 0.011 + 0.311In – 0.35t	0.97
Mc vs Input vs time of DD114 on Barley	Mc = 0.011 + 0.56 In + 0.17t	0.98
Mc vs Input vs time of DD114 on bean	Mc = -19.54 -0.355In + 0.004t	1
CE vs Rey Vs Oe of HD114	Oe = -86 + 0.92CE + 0.93Rey	0.99
CE vs Rey vs Oe of DD114	Oe = -58 + 0.6CE + 0.96 Rey	0.98

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1. CONCLUSION

The following conclusions can be drawn from the study:

- The HD114 machine gives the highest cleaning efficiency in average 96.89% during wheat process and DD114 gives maximum cleaning efficiency in average 95.65% during barley process. The lowest cleaning efficiency was recorded during bean cleaning for HD114 and DD114 that was 80.22% and 80.99% in order.
- Both machines have lowest cleaning loss during wheat process 3.22% and 4.8% in order but they gave maximum cleaning loss during bean process 24.76% and 23.54% for HD14 and DD114 in order.
- HD114 and DD114 gave maximum seed recovery on wheat and bean 92.6% and 91.43% in order and HD114 gave 83.76% lowest seed recovery during wheat process and DD114 gave 61.44% the least seed recovery during bean cleaning.
- Overall efficiency of machine were maximum for both machines as it recorded 89.75% and 84.83% during wheat processing and both machine gives lowest overall efficiency during bean process 72.27% and 61.44% for HD114 and DD114 in order.
- Performance of machine was significantly affected by feeding mass and type of seed under process.
- As feeding mass increase cleaning efficiency and overall machine efficiency were decline and cleaning loss was raised.
- HD114 gives maximum performance on wheat cleaning and bean cleaning and DD114 was gives excellent performance during both barley and wheat processing.
- Both machines have maximum performance on wheat processing and minimum performance on bean processing.
- Statically analysis show that both machines can't perform the same during different level of feeding and with variety of seed
- The study clearly indicated that processing cereals by Delta machine gives maximum performance than processing legumes and others by them.

5.2. RECOMMENDATION

- Oromia seed enterprise machines have high performance on wheat and barley cleaning. If Oromia seed enterprise use these machines for cereals crop cleaning they will get great machine performance and profit from their machines.
- To do bean cleaning by Oromia seed cleaning machine it need possible adjustments and repair and maintenance issues for Delta 114 seed cleaner. Because there was great seed loss during bean cleaning in both cleaning center. Unless otherwise Oromia seed enterprise face loose seed quality and money if they continue cleaning bean by these seed cleaning machines.

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APPENDIX

Appendix Table 1: Test Result HD114 seed cleaner Machine capacity on wheat

No	Feeding (ton)	Output (ton)	Time (hr.)	Machine capacity (ton.hr^{-1})
1	0.20	0.19	4	0.050
2	0.21	0.19	3.92	0.054
3	0.29	0.27	3.92	0.074
4	0.30	0.27	3.92	0.077
5	0.30	0.27	3.92	0.076
6	0.30	0.28	3.92	0.076
7	0.30	0.28	3.92	0.077
8	0.32	0.27	3.92	0.08
9	0.44	0.41	11	0.04
10	0.46	0.38	11	0.044
11	0.50	0.46	11	0.045
12	0.54	0.48	11	0.05
13	0.59	0.58	11	0.054
14	0.63	0.59	11	0.06
15	0.66	0.65	11	0.061
16	0.68	0.64	11	0.062
17	0.73	0.69	11	0.064
18	0.745	0.71	11	0.065
19	0.75	0.70	11	0.007
Mean				**0.0619**

Appendix Table 2: Test Result HD114 seed cleaner Machine capacity on barley

No	Feeding(ton)	Output(ton)	Time (hr.)	Machine capacity (ton.hr^{-1})
1	0.097	0.090	4	0.024
2	0.099	0.099	4	0.025
3	0.112	0.880	4	0.028
4	0.127	0.132	4	0.032
5	0.128	0.140	4	0.032
6	0.135	0.130	4	0.033
7	0.142	0.130	4	0.034
8	0.176	0.177	4	0.043
9	0.225	0.168	3.5	0.065
10	0.240	0.214	11	0.022
11	0.247	0.195	9	0.027
12	0.270	0.240	11	0.025
13	0.277	0.236	11	0.025
14	0.300	0.270	11	0.027
15	0.307	0.300	11	0.028
16	0.320	0.325	11	0.035
17	0.322	0.255	11	0.030
18	0.337	0.265	11	0.031
19	0.390	0.384	11	0.035
20	0.417	0.395	11	0.033
21	0.420	0.360	11	0.034
22	0.424	0.371	11	0.042
23	0.480	0.473	11	0.043
	Mean			**0.0432**

Appendix table 3: Test Result HD114 seed cleaner Machine capacity on bean

No	**Feeding (ton)**	**Output (ton)**	**Time (hr.)**	**Machine Capacity (ton.hr^{-1})**
1	0.036	0.032	1	0.037
2	0.073	0.066	1.5	0.0486
3	0.17	0.14	3	0.057
Mean				**0.0475**

Appendix Table 4: Test Result DD114 seed cleaner Machine capacity on bean

No	**Feeding (ton)**	**Output (ton)**	**Time (hr.)**	**Machine capacity (ton.hr^{-1})**
1	0.018	0.004	2	0.0094
2	0.022	0.018	2	0.011
3	0.029	0.022	6	0.005
4	0.123	0.088	6	0.02
5	0.130	0.100	5	0.03
6	0.152	0.104	9	0.017
7	0.156	0.108	10	0.016
8	0.170	0.116	10	0.017
9	0.177	0.124	10	0.018
Mean				**0.015**

Appendix table 5: Test Result DD114 seed cleaner Machine capacity on Wheat

No	Feeding (ton)	Output(ton)	time(hr)	Machine capacity (ton.hr^{-1})
1	0.109.3	0.097.5	3	0.036
2	0.123	0.101.5	3	0.04
3	0.130	0.113.5	3	0.043
4	0.196	0.171	4	0.047
5	0.228	0.198	6	0.038
6	0.239	0.191	6	0.040
7	0.275	0.250	5	0.054
8	0.300	0.264	10	0.030
9	0.327	0.286	10	0.032
10	0.335	0.276	10	0.034
11	0.346	0.305	10	0.035
12	0.348	0.295	10	0.035
13	0.357	0.313	10	0.036
14	0.358	0.302	10	0.014
15	0.363	0.312	10	0.036
16	0.364	0.319	10	0.040
17	0.387	0.335	10	0.040
18	0.412	0.354	10	0.041
19	0.419	0.340	10	0.042
20	0.434	0.389	10	0.044
21	0.444	0.403	10	0.044
22	0.446	0.401	10	0.045
23	0.454	0.411	10	0.045
24	0.483	0.433	10	0.048
25	0.485	0.437	10	0.049
26	0.486	0.441	10	0.049
27	0.597	0.526	9	0.066
	Mean			**0.042**

Appendix Table 6: Test Result DD114 seed cleaner machine capacity on barley

No	Feeding (ton)	Output (ton)	Time (hr)	Machine capacity (ton.hr^{-1})
1	0.041	0.032	1	0.041
2	0.059	0.048	2	0.03
3	0.200	0.161	6	0.033
4	0.203	0.164	4	0.051
5	0.235	0.204	10	0.025
6	0.247	0.207	10	0.025
7	0.372	0.316	10	0.037
8	0.377	0.338	10	0.037
9	0.400	0.350	10	0.040
10	0.410	0.342	10	0.041
11	0.416	0.354	9	0.046
12	0.448	0.400	10	0.045
13	0.478	0.424	10	0.048
14	0.497	0.416	10	0.065
Mean				**0.0392**

Appendix table 7: HD114 CE and CL for Wheat

No	Feeding (kg)	Output seed(kg)	Cleaning efficiency (%)	Cleaning loss (%)
1	200	190.5	98.45	1.57
2	210	195	97.99	2.05
3	290	277	98.16	1.88
4	300	277.5	97.88	2.16
5	300	278	97.37	2.70
6	300	282	97.27	2.80
7	300	289	97.27	2.80
8	315	278.5	96.80	3.30
9	440	415	96.78	3.33
10	460	387.5	96.75	3.35
11	500	461.5	96.73	3.38
12	540	483	96.72	3.40
13	580	511.5	96.42	3.71
14	630	593.5	96.33	3.81
15	660	623.5	96.09	4.07
16	680	628.5	96.07	4.09
17	730	693	96.05	4.11
18	745	705	95.89	4.28
20	750	700	95.80	4.39
Mean			**96.89**	**3.22**

Appendix table 8: HD114 CE and CL for Barley

No	Feeding (kg)	Output (kg)	Loss (kg)	Cleaning efficient (%)	Cleaning loss (%)
1	97.5	90.625	4.12	95.65	4.55
2	99.75	78.75	4.55	94.54	5.78
3	112.5	88.125	5.1	94.53	5.79
4	127.5	96.7	5.8	94.34	6.00
5	135	110.12	6.87	94.12	6.24
6	142.5	130.62	8.4	93.96	6.43
7	225	150.75	10.2	93.66	6.77
8	240	200.37	13.8	93.56	6.89
9	247.5	195	13.5	93.53	6.92
10	270	230.75	16.4	93.36	7.11
11	277.5	236.87	17	93.30	7.18
12	300	268	20	93.06	7.46
13	307.5	265.62	20	93.00	7.53
14	322.5	255.5	20.2	92.69	7.89
15	330	298.5	23.9	92.59	8.01
16	337.5	265	24	91.70	9.06
17	390	344.8	31.7	91.58	9.19
18	417.6	375	34.7	91.53	9.25
19	420	360.63	35	91.15	9.71
20	424	371.37	35.7	91.23	9.61
21	480	403.25	45.7	89.82	11.33
Mean				**92.99**	**7.56**

Appendix table 9: HD114 CE and CL for Bean

No	Feeding (kg)	Output (kg)	Loss (kg)	cleaning efficiency (%)	cleaning loss (%)
1	36.5	25	5	83.33	20
2	73	48.5	12.52	79.48	25.81
3	171.5	115	32.75	77.83	28.48
Average				**80.22**	**24.764**

Appendix table 10: DD114 CE and CL for Wheat

No	Feeding (kg)	Output (kg)	Loss (kg)	Cleaning efficiency (%)	Cleaning Loss (%)
1	109.3	97.5	0.2	99.80	0.2
2	123	101.5	1.03	99.00	1.0
3	130.2	111.5	1.3	98.85	1.2
4	196	171	3	98.28	1.8
5	228	197.1	3.8	98.11	1.9
6	239	191.5	4.1	97.90	2.1
7	275	245	4.9	98.04	2.0
8	300.3	286.5	8.1	97.25	2.8
9	327	286.5	8.45	97.14	2.9
10	335	270	8.5	96.95	3.1
11	346.4	296	9.8	96.80	3.3
12	348	285	11	96.28	3.9
13	357	303	11.9	96.22	3.9
14	358.6	292	14	95.42	4.8
15	363.6	293	14.7	95.22	5.0
16	364	303	16	94.98	5.3
17	387.4	319	17.2	94.88	5.4
18	412	340	18.4	94.87	5.4
19	419	308	18.5	94.33	6.0
20	434.4	389	23	94.42	5.9
21	444	383	23.5	94.22	6.1
22	446	380	28	93.14	7.4
23	454	402	30	93.06	7.5
24	483	413	38.7	91.43	9.4
25	485	414.5	42	90.80	10.1
26	486	414.7	42.8	90.64	10.3
27	597	506	52.7	90.57	10.4
Mean				**95.50**	**4.8**

Appendix 11: DD114 CE and CL for Barley

No	Feeding (kg)	Output (kg)	Loss (kg)	Cleaning efficiency (%)	Cleaning Loss (%)
1	41	32.5	1	97.01	3.08
2	59.5	48.5	1.5	97.00	3.09
3	200	160	5	96.97	3.13
4	203.7	164	5.8	96.58	3.54
5	235	200	7.1	96.57	3.55
6	247	207.5	7.8	96.38	3.76
7	372	310	11.8	96.33	3.81
8	377	337.5	14.7	95.83	4.36
9	400	350	15.4	95.79	4.40
10	410	342	16	95.53	4.68
11	416.7	344	16.8	95.34	4.88
12	448	400	28.5	93.35	7.13
13	478	414.5	30	93.25	7.24
14	497	416	30.7	93.13	7.38
Mean				**95.65**	**4.57**

Appendix 12: DD114 CE and CL for Bean

No	Feeding (kg)	Output (kg)	Loss (kg)	Cleaning efficiency (%)	Cleaning Loss (%)
1	18.9	14	2.3	85.89	16.43
2	22.5	15.8	3.5	81.87	22.15
3	29.4	18	4.3	80.72	23.89
4	123	72.7	17.3	80.78	23.80
5	130	82.2	19.8	80.59	24.09
6	152	85.3	20.7	80.47	24.27
7	156.6	87.9	22	79.98	25.03
8	170	93.9	23.7	79.85	25.24
9	177	102	27.5	78.76	26.96
Mean				**80.99**	**23.54**

Appendix table 13: Comparisons of HD 114 and DD 114 on different parameters

Parameters	Different comparisons of HD114 and DD114 seed cleaner			
	Seed cleaners	**Wheat**	**Barley**	**Bean**
Cleaning efficiency (%)	HD114	96.89	92.99	80.22
	DD114	95.50	95.65	80.99
Cleaning Loss (%)	HD114	3.22	7.56	24.76
	DD114	4.8	4.57	23.54
Seed Recovery (Rey, %)	HD114	92.6	83.76	91.43
	DD114	84.83	84.03	61.44
Overall efficiency (%)	HD114	89.75	77.89	72.27
	DD114	84.83	84.03	61.44
Feed Rate (Fr, ton.min^{-1})	HD114	1.03	0.54	0.79
	DD114	0.7	0.65	0.26