Wheat crop thresher had been designed, manufactured and tested in the workshop of the department of agricultural engineering, faculty of agricultural sciences, university of Dongola, northern state of Sudan under collaboration of Alshamaliya for Agricultural Services Company, for small-scale farmers were made simple and includes threshing cylinder, concave, shaker, pulleys and sieve. For purpose of improving thresh efficiency the cylinder-concave clearance was made adjustable at two points. The thresher was tested for wheat variety (Imam) at two levels of concave-clearance (15, 20 mm), two fan speeds (1042, 1390 rpm), two cylinder speeds (650, 900 rpm) and two cylinder types using (rasp-bar type, wire-loop type) three replications in a randomized complete block design. Results obtained showed a high efficiency of threshing at clearance 20 mm in fan speed of 1390 rpm at a cylinder speed of 900 rpm and rasp-bar type cylinder. The shape and diameter of concave and sieve holes which designated according to the geometric mean diameter for tested wheat has given a very good results based on threshing efficiency (TE), separation losses (SL), cleaning efficiency (CE) and product purity (Pp) which were 69.9 %, 30.1 %, 82.3 % and 93.2 % respectively.

Key Words: Wheat crop thresher, Small-scale farmers, Geometric mean diameter.
1. Introduction:

Wheat in the Sudan is predominantly produced in the irrigated production system and has been targeted as a major food security crop in the Sudan since the 1980s (El Faki, 2000). The average area allocated for wheat represented only 3% of total area under cereals but still accounting for about 11.7% of total cereal production during the period from 2006-2009 (MoFEP, 2012). Other cereals (mainly sorghum and millet) are produced in the rain fed system. Most known areas for wheat production include Gezira and New Halfa schemes, Northern, River Nile and White Nile states.

Generally, the average wheat yields in Sudan are very low and uncertain (Saad, 2010). The major reasons for low productivity and instability in addition to heat stress also includes late planting of wheat, non-availability of improved inputs like seed, inefficient fertilizer use, weed infestation, shortage of irrigation water and delayed harvesting. Moreover, farmers are not aware of modern technologies because of weak extension services system (Kabesh et al., 2009).

Wheat harvesting in Northern State is the most tedious and the most costly agricultural operation. It costs about 20% of the total variable cost of agricultural production next to irrigation cost (31.5%), (Fageeri, 2005). Farmers manually cut the crop using sickles, tie it into bundles and collect it on a heap, which is later threshed using stationary thresher.

Many types of processing equipment have been developed and used in many parts of the world for grain threshing; however, most of these machines are expensive and require high power to operate, which are therefore beyond the reach of majority of small scale farmers. Hence, there is need to design, fabricate and evaluate wheat crop thresher which is portable, low cost and can operate with electric motor or diesel engine in rural areas.

2. Literature reviews:

Proper design of machines and processes to harvest, handle and store agricultural materials and to convert these materials into food and feed requires an understanding of their physical properties. Strivastava et al., (1990) noted that the grain separation is very sensitive to variation in the physical properties of grain, straw and chaff.

Many researchers have investigated that fan speed, cylinder speed and concave clearance are the key machine parameters that can influence the threshing efficiency of a mechanical thresher (Singh et al., 1981; Joshi et al., 1981; Ghaly, 1985; Behera et al., 1990).

Ponican et al., (2009) investigated threshing mechanism parameters of maize crop. They concluded that peripheral speed and clearance between cylinder and concaves were the most important factors affecting the crop quality.

Sarwar and Khan (1987) compared the performance of rasp-bar and wire-loop cylinders for threshing rice crop. They reported that the rasp-bar gave higher percentage of husked grain than wire-loop for all levels of evaluated peripheral speeds. Addo et al., (2004) reported that the rasp-bar drum type provides more surface area for frictional impact.

Arnold (1964) reported that increasing concave length increased concave separation. The effect of concave length when threshing wheat and barley was studied by Cooper (1978). He reported that a 25% increase of arc from 84° to 105° increased grain separation by 17%.

Singh and Kumar (1976) reported that increasing the cylinder speed decreases un-threshed seed. Dash and Das (1989) stated during development of power operated paddy thresher that, paddy crop with high cylinder peripheral velocity in order to minimize the total un-threshed loss. Abo El-Khair (1991) concluded that the un-threshed seed losses decreased with an increase in drum speed. El-Haddad (2004) designed and manufactured chopping, threshing and winnowing machine suitable for the requirements of some crops residues recirculation. The experimental results showed that the un-threshed grain losses was decreased as the cylinder speed was increased.

According to Kolganov (1956) the higher cylinder speeds cause damage to the seeds. Vas and Harison (1969), noted that the cylinder speed was an influencing factor as far as grain damage in
wheat was concerned. Singh and Kumar (1976) reported that increasing the cylinder speed increases grain damage. Kumar and Goss (1979) used data obtained from 224 field experiments to present models for combine performance. Model presented for broken seeds indicated significant correlation between cylinder speed and seed breakage. They found that an increase from 6 to 9% in broken seeds could be observed by an increase in cylinder speed from 20 to 25 m sec$^{-1}$. Joshi and Singh (1980) developed Pantnagar IRRI multi-crop thresher. They observed that increase in cylinder speed reduces the cylinder loss at the cost of increase in visible damage for all the cylinder concave clearance. Sharma and Devnani (1980) at higher speeds, the visible grain damage was 5%. Singh et al. (1981) investigated the effect of crop and machine parameters on threshing effectiveness and seed quality of soybean. They determined the external damage inflicted on the grain by finding the weight of broken grains in specified samples. They found that external damage increased with increase in cylinder speed. Anwar and Gopta (1990) reported that the percentage of grain damage increased with an increase in drum speed for all feed rates and concave combinations. Alonge and Adegbulugbe (2000) stated that kernel damage increases as the speed of the machine increases. Sudajan et al., (2002) reported that visible grain damage increased with increasing drum speed. Johnson (2003) proposed that a thresher should be operated at the lowest cylinder speed that will shed the most grain with acceptable levels of damage to grain. The effect of drum speed was investigated on percentage of damaged grains and threshed pods in a finger type thresher for chickpea (Khazaei et al., 2003). Results indicated that the drum speed had the highest effects on the intensity of damage. El-Haddad (2004) designed and manufactured chopping, threshing and winnowing machine suitable for the requirements of some crops residues recirculation. The experimental results showed that the visible grain damage increased as the cylinder speed increased. Vejasit and Salokhe (2004) studied machine-crop parameters of an axial flow thresher for soybean and reported that threshing drum speed significantly affected the grain damage during soybean threshing. Askari Asli–Ardeh et al., (2008) during the test of a power tiller operated small thresher concluded that grain damage increased with increasing peripheral speed. Chimchana et al., (2008) developed an unequal speed co-axial split-rotor thresher for rice. Results of their study indicated that optimum speed for threshing rotor was considered to be 600 rpm and by increasing this speed above 800 rpm the grain damage was increased. Ponican et al., (2009) investigated threshing mechanism parameters of maize crop. Their experiment results with the tangential threshing mechanism showed that with increasing the cylinder peripheral speed from 9.4 to 21.4 m s$^{-1}$, the grain damage increased from 3.8 to 6.01%.

The studies made by Singh and Kumar (1976) showed that increasing cylinder tip speed increases threshing efficiency. Ige (1978) studied the threshing and separation performance of a locally built cowpea thresher. The results showed that the speed of drum affected the threshing efficiency of cowpea. Sharma and Devnani (1980) reported that threshing efficiency increased with the increase of cylinder speed. Desta and Mishra (1990) developed and conducted performance evaluation of a sorghum thresher. Their results showed that threshing efficiency increased with an increase in cylinder speed for all feed rate and cylinder concave clearances. Hadad (2000) stated that the threshing efficiency increased with increasing drum speed and decreasing feed rate. Simonyan and Oni (2001) reported that the threshing effectiveness was also found to be affected by the cylinder speed. El-Haddad (2004) designed and manufactured chopping, threshing and winnowing machine suitable for the requirements of some crops residues recirculation. The experimental results showed that the threshing efficiency increased as the cylinder speed increased. Vejasit and Salokhe (2004) studied machine-crop parameters of an axial flow thresher for soybean and reported that threshing drum speed significantly affected the threshing efficiency during soybean threshing. According to Adewumi et al., (2007) the results of the performance analysis showed that threshing efficiency increased with an increase in cylinder speed and threshing efficiencies was found to be in the range of 54.5% to 100%. Radwan et al., (2009) performed study on the El-Shams type tangential axial flow cereal thresher as developed. It was found that increasing rotor speed tends to increase the threshing efficiency. At air speed (4.8m/s) and moisture content (10.36%), increasing rotor speed from 500 to 700rpm increased the threshing efficiency from 70.2 to 73.7%.

Joshi and Singh (1980) developed Pantnagar IRRI multi-crop thresher. They observed that cleaning efficiency increased with an increase in the cylinder speed of the thresher.
3. Materials and methods:

3.1. Determination of geometric mean diameter:

A vernier caliper was used to measure three perpendicular diameters for wheat kernels with 0.05 mm accuracy. In the case of seeds and grains, length, width, and thickness are often used, respectively, to designate the maximum, average, and minimum diameters (Edison and Brogan, 1972). From these axial dimensions, Dp for the seeds were determined as the geometric mean of the three dimensions given as (Mohsenin, 1970).

\[ D_p = \left(\frac{a \times b \times c}{3}\right)^{\frac{1}{3}} \]

Where: \( a \) = length, \( b \) = width and \( c \) = thickness

3.2 Determination of the kernels mass:

A digital (electronic) scale was used to measure kernel weights for mass with 0.05 g accuracy. The average maximum, and minimum weight for each wheat kernels were determined.

3.3. Physical properties of tested wheat:

Hundred samples of randomly selected wheat kernels of a local Sudanese variety Imam, were measured for length, width, thickness, mass (n=1000 kernels) and geometric mean diameter as given in Table 1;

<table>
<thead>
<tr>
<th>Physical properties</th>
<th>min</th>
<th>max</th>
<th>mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length l, mm</td>
<td>5.40</td>
<td>7.20</td>
<td>6.26</td>
</tr>
<tr>
<td>Width w, mm</td>
<td>2.70</td>
<td>3.50</td>
<td>3.10</td>
</tr>
<tr>
<td>Thickness t, mm</td>
<td>2.20</td>
<td>3.40</td>
<td>2.79</td>
</tr>
<tr>
<td>1000 kernel mass, g</td>
<td>36.99</td>
<td>38.36</td>
<td>37.57</td>
</tr>
<tr>
<td>Geometric mean diameter mm</td>
<td>3.17</td>
<td>4.40</td>
<td>3.78</td>
</tr>
</tbody>
</table>

3.4. Screen characteristics:

Screens are characterized by parameters such as shape of opening, effective size of opening and the coefficient of opening, \( C_o \).

For circular opening:

\[ C_o = \frac{\text{Opean Area}}{\text{Total Area}} = \frac{3\pi}{2} \times \frac{D^2}{(D + d)^2} \]

Where:
\( D \) = diameter of hole = 2 mm
\( d \) = distance between the successive holes = 4.5 mm

For efficient screening, \( C_o \) is taken as 40% (Igbeka, 1984).

Screen size selection for this wheat cleaner is such that the screen retains whole kernels until channeled into the good receptacle, broken kernel and other undersize contaminant passes through it. Screen diameter of 2 mm was chosen.
3.5. Machine specifications:

The specification of the wheat crop thresher as at the time of construction is shown in Table 2 below.

### Table 2: Machine Specification

<table>
<thead>
<tr>
<th>Component</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall length</td>
<td>3025mm</td>
</tr>
<tr>
<td>Overall width</td>
<td>1500mm</td>
</tr>
<tr>
<td>Overall height</td>
<td>1550mm</td>
</tr>
<tr>
<td>Machine capacity</td>
<td>75 kg/h</td>
</tr>
<tr>
<td>Power requirement</td>
<td>5hp with 1390rpm</td>
</tr>
<tr>
<td>Power transmission</td>
<td>V-belts drive with pulley diameters 45mm, 96 or 69.5mm, 285mm and 60 or 45mm</td>
</tr>
<tr>
<td>Type of the cylinder</td>
<td>Rasp-bar type cylinder and wire-loop type cylinder with 84 wire-loops</td>
</tr>
<tr>
<td>Hole concave sieve (round)</td>
<td>Ø5mm</td>
</tr>
<tr>
<td>Fan</td>
<td>Radial fan with 8 blades</td>
</tr>
<tr>
<td>Fan blade size</td>
<td>800mm by 130mm</td>
</tr>
<tr>
<td>Fan Housing</td>
<td>Ø450mm by 850mm</td>
</tr>
<tr>
<td>Airflow channel inlet size</td>
<td>15mm by 850mm</td>
</tr>
<tr>
<td>Fan shaft</td>
<td>Ø22mm by 1000mm</td>
</tr>
<tr>
<td>Number of sieves (flat)</td>
<td>1; 1200mm by 800mm</td>
</tr>
<tr>
<td>hole sieve diameter (round)</td>
<td>Ø2mm</td>
</tr>
<tr>
<td>Connecting rod length</td>
<td>300mm</td>
</tr>
<tr>
<td>Crank speed</td>
<td>208.5rpm</td>
</tr>
</tbody>
</table>

4.6. Experimental design:

The threshing machine was designed and manufactured for threshing wheat crop in Agricultural Engineering Department, Faculty of Agricultural Sciences, University of Dongola, northern state of Sudan under collaboration of Alshamaliya for Agricultural Services Company.

Wheat materials (360 kg variety Imam) was manually collected by hand pulling from the farm of the Dongola Research Station. Each half of the collected material was divided into 48 bundles (7.5 kg each) and each bundle was fed to the locally made machine.

The study operating parameters include:

Two levels of drum speed; DS1= 650 rpm and DS2= 900 rpm.
Two levels of fan speed; FS1= 1042 rpm and FS2= 1390 rpm.
Two levels of concave - drum clearance; C1= 15 mm and C2= 20 mm.
Two types of threshing drum; TD1= rasp-bar drum and TD2= wire-loop drum.

Randomized complete block design was used with sixty treatments replicated three times. For each replication in each treatment the following measurements was made:

Threshed grains by weight (g), Un-threshed grains by weight (g), Grains blown out with chaff by weight (g), Total grains by weight (g), Broken grains by weight (g), Grains with stem by weight (g).

Threshing efficiency (Alizadeh and Bagheri, 2009) is the ratio of total weight of grain threshed to the total weight of grains fed into the threshing, that expressed in percentage. It can be evaluated by equation (3):

\[
\text{Threshing efficiency (\%)} = \frac{\text{Weight output}}{\text{Weight input}} \times 100 \% \quad (3)
\]

Separation losses (Asli-Ardeh \textit{et al.}, 2009) is the ratio of total weight of un-threshed grain to the total weight of grains fed into the threshing that expressed in percentage. It can be evaluated by equation (4):

\[
\text{Separation losses (\%)} = \frac{\text{Un-threshed weight}}{\text{Weight input}} \times 100 \% \quad (4)
\]

Cleaning efficiency (Agidi \textit{et al.}, 2013) is the ratio of mass of separated impurities to the total mass of impurities in the millet expressed in percentage and is given as:

\[
\text{Cleaning efficiency (\%)} = \frac{\text{mass of separated impurities}}{\text{mass of un-separated impurities}} \times 100 \% \quad (5)
\]

Product purity (Igbeka, 1984) this was obtained as the ratio of weight of whole wheat grains in the products to the total weight of products.

\[
\text{Product purity (\%)} = \frac{\text{GP}}{\text{GP} + \text{BP}} \times 100 \% \quad (6)
\]

Where:

- GP is the weight of clean wheat grain in the clean grain outlet, kg.
- BP is the weight of materials other than grains collected in the clean grain outlet, kg.

The data obtained were statically analyzed using GenStat software edition 3 to determine the effect of cylinder speed, fan speed, concave-cylinder clearance and cylinder type on the above mentioned variables.

3.7. Operating principle:

The operation of the wheat crop threshers can be described as follow:

The materials from farmer-harvested wheat grain plants are fed in to the threshing cylinder to flow down freely and directly to the sieve supported by gravity and concave. while shaking, small materials other than healthy wheat grains (including broken grains and half-matured grains) drop down to the trash pan.

Air from the high capacity fan is directed to get rid of lighter trashes, whereas clean wheat grains is forwarded to the clean grain pan supported by gravity and inclination which is controlled manually by jackscrew in front of the machine (Figure 1 and Figure 2).
Design, Fabrication and Performance Evaluation of Wheat Crop Thresher for Small-Scale Farmers

Figure 1: Schematic diagram of the wheat crop thresher
1- screw jack, 2- high capacity fan, 3- electric motor, 4- frame, 5- threshing cylinder, 6- trashes pan, 7- threshing drum, 8- shaker, 9- bearing, 10- sieve, 11- driving wheel, 12- drum pulley, 13- bearing housing, 14- shaker pulley, 15- clean grain pan, 16- fan pulley, 17- crank

Fig. 2: (a) prototype of wheat thresher, (b) threshing drum and concave, (c) clean grain pan
Table 3: Effect of different drum speed, fan speed, concave - drum clearance and type of drum on performance parameters

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Threshed grains (g)</td>
</tr>
<tr>
<td>CS1×FS1×C1×TD1</td>
<td>2337.3 e</td>
</tr>
<tr>
<td>CS1×FS1×C1×TD2</td>
<td>2329.3 f</td>
</tr>
<tr>
<td>CS1×FS1×C2×TD1</td>
<td>2374.3 d</td>
</tr>
<tr>
<td>CS1×FS1×C2×TD2</td>
<td>2372.3 d</td>
</tr>
<tr>
<td>CS1×FS2×C1×TD1</td>
<td>2358.3 e</td>
</tr>
<tr>
<td>CS1×FS2×C1×TD2</td>
<td>2356.3 e</td>
</tr>
<tr>
<td>CS1×FS2×C2×TD1</td>
<td>2392.3 c</td>
</tr>
<tr>
<td>CS1×FS2×C2×TD2</td>
<td>2388.3 d</td>
</tr>
<tr>
<td>CS2×FS1×C1×TD1</td>
<td>2408.3 c</td>
</tr>
<tr>
<td>CS2×FS1×C1×TD2</td>
<td>2404.3 c</td>
</tr>
<tr>
<td>CS2×FS1×C2×TD1</td>
<td>2465.3 a</td>
</tr>
<tr>
<td>CS2×FS1×C2×TD2</td>
<td>2455.3 b</td>
</tr>
<tr>
<td>CS2×FS2×C1×TD1</td>
<td>2445.3 b</td>
</tr>
<tr>
<td>CS2×FS2×C1×TD2</td>
<td>2435.3 b</td>
</tr>
<tr>
<td>CS2×FS2×C2×TD1</td>
<td>2480.7 a</td>
</tr>
<tr>
<td>CS2×FS2×C2×TD2</td>
<td>2472.3 a</td>
</tr>
<tr>
<td>Pr&gt;F</td>
<td>0.0001**</td>
</tr>
</tbody>
</table>

Means within a group followed by same letter are not significantly different at probability P=0.05 by Duncan’s multiple range test.
4.1 Effect of different drum speed, fan speed, concave - drum clearance and type of drum on Threshed Grains:

The effect of different drum speed, fan speed, concave - drum clearance and type of drum on Threshed Grains is illustrated in Table 3 the results exposed that the difference between treatments were highly significant (P ≤ 0.01) having the highest was (2480.7) g in (CS2×FS2×C2×TD1) and the lowest was (2329.3) g in (CS1×FS1×C1×TD2). Generally, the results indicated that threshed grains increased with increasing the cylinder speed, fan speed, concave - drum clearance at rasp-bar type cylinder. Similar results were achieved by Singh and Kumar (1976), Ige (1978), Sharma and Devnani (1980), Desta and Mishra (1990), Hadad (2000), Simonyan and Oni (2001), El-Haddad (2004), Vejasit and Salokhe (2004), Adewumi et al., (2007) and Radwan et al., (2009). Arnold (1964) reported that increasing concave length increased concave separation. The effect of concave length when threshing wheat and barley was studied by Cooper (1978). He reported that a 25% increase of arc from 84° to 105° increased grain separation by 17%. Sarwar and Khan (1987) compared the performance of rasp-bar and wire-loop cylinders for threshing rice crop. They reported that the rasp-bar gave higher percentage of husked grain than wire-loop for all levels of evaluated peripheral speeds. Addo et al., (2004) reported that the rasp-bar drum type provides more surface area for frictional impact.

4.2 Effect of different drum speed, fan speed, concave - drum clearance and type of drum on Un-Threshed Grains:

The results regarding the Un-Threshed Grains are presented in Table 3. The statistical analysis showed a highly significant difference among treatments (P ≤ 0.01), whereas the lowest was (698.3) g in (CS2×FS2×C2×TD1) and the highest was (746.0) g in (CS1×FS1×C1×TD2). The un-Threshed decreased with an increase in drum speed, fan speed and concave clearance at rasp-bar type cylinder, these results confirm the findings of Singh and Kumar (1976) reported that increasing the cylinder speed decreases un-threshed seed. Dash and Das (1989) stated during development of power operated paddy thresher that, paddy crop with high cylinder peripheral velocity in order to minimize the total un-threshed loss. Abo El-Khair (1991) concluded that the un-threshed seed losses decreased with an increase in drum speed. El-Haddad (2004) designed and manufactured chopping, threshing and winnowing machine suitable for the requirements of some crops residues recirculation. The experimental results showed that the un-threshed grain losses was decreased as the cylinder speed was increased.

4.3 Effect of different drum speed, fan speed, concave - drum clearance and type of drum on Broken Grains:

The results of Broken Grains is exposed in Table 3 which revealed a highly significant difference between treatments (P ≤ 0.01) the highest level of Broken Grains was (125.0) g in (CS2×FS2×C2×TD1) and the lowest level of Broken Grains was (116.0) g in (CS1×FS1×C1×TD2). Generally, the results indicated that total grain damage increased with increasing the cylinder speed, fan speed, concave - drum clearance at rasp-bar type cylinder. Similar results were achieved by Kolganov (1956), Vas and Harison (1969), Singh and Kumar (1976), Kumar and Goss (1979), Joshi and Singh (1980), Sharma and Devnani (1980), Singh et al. (1981), Anwar and Gopta (1990), Alonge and Adegbulugbe (2000), Sudajan et al., (2002), Khazaei et al., (2002), Johnson (2003), Khazaei et al., (2003), El-Haddad (2004), Vejasit and Salokhe (2004), El-Haddad et al., (2006), Askari Asli-Ardeh et al., (2008), Chimchana et al., (2008) and Ponican et al., (2009).

4.4 Effect of different drum speed, fan speed, concave - drum clearance and type of drum on Grains with Chaff:

A highly significant difference between treatments (P ≤ 0.01) was also revealed in relation to Grains with Chaff as illustrated in Table 3. The highest level of Grains with Chaff was (252.7) g in (CS2×FS2×C2×TD1) and the lowest level of Grains with Chaff was (232.7) g in (CS1×FS1×C1×TD2). The grain with chaff increased with an increase in drum speed, fan speed and concave clearance at wire-loop type cylinder. These results coincide with Vejasit and Salokhe (2004).
studied machine-crop parameters of an axial flow thresher for soybean and reported that threshing drum speed significantly affected the grain losses during soybean threshing.

4.5 Effect of different drum speed, fan speed, concave - drum clearance and type of drum on Grains with Stem:

The results pertaining to Grains with Stem of as influenced by different drum speed, fan speed, concave - drum clearance and type of drum are shown in Table 3. The results of analysis of variance indicated a highly significant difference between treatments (P ≤ 0.01) with highest level of Grains with Stem was (188.3) g in (CS2×FS2×C2×TD2) and the lowest level of Grains with Stem was (174.3) g in (CS1×FS1×C1×TD1). The grain with stem increased with an increase in drum speed, fan speed and concave clearance at wire-loop type cylinder. These results coincide with Vejasit and Salokhe (2004) studied machine-crop parameters of an axial flow thresher for soybean and reported that threshing drum speed significantly affected the grain losses during soybean threshing.

4.6 Effect of different drum speed, fan speed, concave - drum clearance and type of drum on Total Grains:

The results of Total Grains as influenced by different drum speed, fan speed, concave - drum clearance and type of drum are given in Table 3. The results illustrated that the difference between treatments were highly significant (P ≤ 0.01) having the highest level of Total Grains was (2918.7) g in (CS2×FS2×C2×TD1) and the lowest level of Total Grains was (2736.7) g in (CS1×FS1×C1×TD2). The total grains increased with an increase in drum speed, fan speed and concave clearance at rasp-bar type cylinder.

4.7 Effect of different drum speed, fan speed, concave - drum clearance and type of drum on Threshing Efficiency %:

The effect of different drum speed, fan speed, concave - drum clearance and type of drum on Threshing Efficiency is illustrated in Table 3. The results illustrated that the difference between treatments were highly significant (P ≤ 0.01) having the highest value of Threshing Efficiency was recorded (69.9 %) in (CS2×FS2×C2×TD1) and the lowest value of Threshing Efficiency was recorded (65.7 %) in (CS1×FS1×C1×TD2). Generally, the results indicated that efficiency of the machine is directly affected by the threshing speed of the cylinder drum, fan speed, concave - drum clearance at rasp-bar type cylinder. Similar results were achieved by Singh and Kumar (1976), Ige (1978), Sharma and Devnani (1980), Desta and Mishra (1990), Hadad (2000), Simonyan and Oni (2001), El-Haddad (2004), Vejasit and Salokhe (2004), Adewumi et al., (2007) and Radwan et al., (2009).

4.8 Effect of different drum speed, fan speed, concave - drum clearance and type of drum on Separation Losses %:

Data regarding Separation Losses are shown in Table 3. The results illustrated that the difference between treatments were highly significant (P ≤ 0.01) having the lowest value of Separation Losses was recorded (30.1 %) in (CS2×FS2×C2×TD1) and the highest value of Separation Losses was recorded (34.3 %) in (CS1×FS1×C1×TD2). The separation losses decreased with an increase in drum speed and with increase in drum concave clearance, fan speed at rasp-bar type cylinder, which is in conformity with Singh and Kumar (1976) reported that increasing the cylinder speed decreases un-threshed seed. Dash and Das (1989) stated during development of power operated paddy thresher that, paddy crop with high cylinder peripheral velocity in order to minimize the total un-threshed loss. Abo El-Khair (1991) concluded that the un-threshed seed losses decreased with an increase in drum speed. El-Haddad (2004) designed and manufactured chopping, threshing and winnowing machine suitable for the requirements of some crops residues recirculation. The experimental results showed that the un-threshed grain losses was decreased as the cylinder speed was increased. Arnold (1964) reported that increasing concave length increased concave separation. The effect of concave length when threshing wheat and barley was studied by Cooper (1978). He reported that a 25% increase of arc from 84° to 105° increased grain separation by 17%.
4.9 Effect of different drum speed, fan speed, concave - drum clearance and type of drum on Cleaning Efficiency %:

The results pertaining to Cleaning Efficiency of as influenced by different drum speed, fan speed, concave - drum clearance and type of drum are shown in Table 3. The results of analysis of variance indicated a highly significant difference between treatments (P ≤ 0.01) with highest level of Grains with Stem was (82.3 %) in (CS2×FS2×C2×TD1) and the lowest level of Cleaning Efficiency was (77.2 %) in (CS1×FS1×C1×TD2). The cleaning efficiency increased with an increase in drum speed, fans peed, concave clearance at rasp-bar type cylinder, which is in conformity with Joshi and Singh (1980) developed Pantnagar IRRI multi-crop thresher. They observed that cleaning efficiency increased with an increase in the cylinder speed of the thresher.

4.10 Effect of different drum speed, fan speed, concave - drum clearance and type of drum on Product Purity:

The effect of different drum speed, fan speed, concave - drum clearance and type of drum on Product Purity is illustrated in Table 3. The results illustrated that the difference between treatments were highly significant (P ≤ 0.01) having the highest value of Product Purity was recorded (89 %) in (CS2×FS2×C2×TD1) and the lowest value of Product Purity was recorded (93.2 %) in (CS1×FS1×C1×TD2). The product purity increased with an increase in drum speed, fans peed, concave clearance at rasp-bar type cylinder.

5. Conclusions:

The following conclusions can be drawn from this research:

- Drum speed, fan speed, concave clearance and drum type play important role in affecting threshed grain quality of wheat. Among all these machine and crop parameters, drum speed is most important.
- Fan speed is very critical factor affecting thresher performance with respect to wheat threshing.
- The combination of 900 rpm: drum speed, 20 mm: concave clearance and 1390 rpm: fan speed found optimum to yield high quality grain of wheat and efficient threshing.
- Results obtained showed a high efficiency of threshing at rasp-bar type cylinder.
- The threshing efficiency, separation losses, cleaning efficiency and product purity which were 69.9 %, 30.1 %, 82.3 % and 93.2 % respectively.

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