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EFFECTS OF TRACTOR SPEEDS ON THE PERFORMANCE OF A KENAF HARVESTING MACHINE

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ABSTRACT

Kenaf(Hibiscus cannabinus L.) may next be an industrial crop based on research findings about its technical and commercial potentials. Field equipment for harvesting kenaf continues to be an important aspect of commercialization. Various studies have drawn attention to the need to develop an efficient kenaf harvesting machine. In this study, a rotary serrated cutting system kenaf harvesting machine developed at Universiti Putra Malaysia and kenaf varieties V36 and Fh 952 were used for the experiment. The effects of tractor speeds on the performance of the machinewere investigated. Seven different tractor speeds, 2.0, 2.5, 3.7, 4.6, 5.8, 6.9, and 7.7km/hr. were used.Based on the results of the experiments, the tractor speed had significant effect on the performance of the machine in terms of its effective field capacity and the machine capacity.The optimum operating forward speed that gave the highest efficiency of 76% was 3.7 km/h.

Keywords: *cutting speed, harvester, kenaf, stem, machine capacity*

INTRODUCTION

Consumption of wood-based products is on the increase, as a result there is a decrease in forest resources, which lead to demand for supplemental non-wood fiber sources. Kenaf (Hibiscus cannabinus L.) is an annual plant with a high fiber yield [1-3]. High CO2 fixation ability of kenaf has increased its global interest as a source of cellulose fiber [4, 5]. Hence, the use of kenaf as an alternative raw material to wood will reduce deforestation, and increase environmental stabilities. It is a third world crop after wood and bamboo; it is introduced as a renewable source of industrial crop in the so-called developed economies. It is an annual warm-season fiber crop that grows in temperate and tropical areas [6]. Its stems comprises of two important components: bastfibers in the bark, and core fibers in the center of the stems [2, 3, 7]. The inner core fiber is about 60 -75%, which produces low quality pulp, and an outer bast fiber 25–40%, which produces high quality pulp, in the stem [6]. Kenaffibers can be blended with synthetic fibers for making carpet. The fiber can also be used in making coarse bags, ropes, nets etc.[8, 9].Kenaf industrial applications include automobile, agriculture, construction, chemical process and packaging. Apparel fabrics and plastic/fiber composites from the fiber are its major end-use products. Other end use products include; fibreboard and particle board, oil and chemical absorbents, animal bedding and horticulture potting mix from the core; livestock feed from the leaf [10-12]. Generally forage harvesters are used for harvesting of kenaf, however, forage harvesters cut the stems into too short fragments [13]. The development of whole-stalk harvesters has taken two major approaches; forage-type harvesters and sugarcane-type harvesters. Scientists and industries have concentrated on adapting existing equipment in both approaches, rather than developing a totally unique kenaf harvester [14]. Standard equipment for forage cutting, baling and chopping was used for kenaf harvesting [15]. Regular farm balers did not satisfactorily bale finely chopped kenaf[16]. Kenaf harvester was developed using a small sugarcane harvester [14]. This machine enabled to harvest it while avoiding cutting stems into too short fragments. Also sugar cane harvesters, with or without modification, have also been used to harvest kenaf. Drawbacks of the sugarcane-type harvesting systems include the transport and storage of the low density stalks or stalk segments [14]. It has been identified as a high income crop, the harvesting, storage, transportation, and post-harvest processes are still labour intensive and time consuming [3]. The evaluation of procedures for harvesting kenaf continues to be an important aspect of commercialization [17].

The objective of this study is to investigate the effects of tractor speeds on the performance of a kenaf harvesting machine developed at Universiti Putra Malaysia.

MATERIALS AND METHODS

A kenaf harvesting machine that can harvest both broadcast and row planted kenaf was used for the experiment (fig. 1). The specifications of the harvester are given in Table 1.

Fig. 1: Broadcast/row planted kenaf harvester

Table 1: Technical Details of the new Kenaf Harvester

Fabricators	*MaliftSdn. Bhd.*
Model Name	
General Dimensions	
Overall length	2968 (mm)
Overall width	685 (mm)
Overall height	920(mm)
Ground clearance	150 (mm)
Total weight	400 (kg)
Transmission	
Power source	Tractor/PTO
Tractor required	55~70 (hp)
PTO	540 (rpm)
Transmission	PTO/hydraulic system/chain-sprocket/hydraulic motor
Harvesting Head (Cutting System & Gathering	
Number of harvesting rows	Broadcast/row
Length	980 (mm)
Width	1630 (mm)
Height	920 (mm)
Height adjustment	Hydraulic system
Cutting System	
Type	Rotary serrated saw type
Cutting system width	980 (mm))
Cutting system height from the ground surface	150 (mm)
No. of grabbing fingers	3
No. of rotary shaft	1
Transmission	Hydraulic motor, Chain – sprocket
No. of tires	1

Kenaf Harvesting Machine Configuration

Solid works 2012 software was used in the production of the conceptual design of the kenaf harvesting machine. In carrying out the design, the following criteria were considered:

- Not complex in design, but simple in construction and operation, which will aid easy operation and maintenance.
- Uses hydraulic system to operate for easy manoeuvring within a smallest available cropping area.
- Simple and cost effective design for maximum profit with readily available spare parts in the market. This modification has reduced the blade sizes usually associated with harvesters or choppers.
- The nature of this design putting into consideration the critical and over-load situation of cutting such as, maximum forward speed, broadcast planted stem distance, and unpredictable critical conditions. This machine can harvest several stems at any single operation at a time.
- Minimum cutting height adjustable by the tractor hydraulic system which results in a moderately and uniform cutting height on a flat and well levelled cultivated land.
- Excellent machine stability on transit.
- Operator safety was highly considered in the design

Harvester Description and Principles of operation

The developed kenaf harvester is a simple to operate, maintain and compact machine which is being operated by hydraulic system. It was also developed in such a manner that can easily be transported to and from the farm on narrow farm roads. It comprises of three major operating systems; the hydraulic, the cutting and the gathering systems. The hydraulic system which serves as the source of power to the other systems consists of the hydraulic tank, filter, pump, motor, control and the hoses. The hydraulic fluid stored in the tank is pumped by the hydraulic pump which passes through the filter for effective cleaning of the complete system in order to achieve good performance. This then drives the hydraulic motor which transfers power through shafts, chains and sprockets to the other systems.

The cutting system has four rotary serrated saw cutting blades arranged in series at overlap positions in order to have effective cutting without missing any kenaf stem. This covers a length of 98cm of the effective cutting width of the harvester. It drives its power from the harvester hydraulic system by means of chains and sprockets. The gathering system consists of rotary grabbing fingers mounted right on top of the cutting system, this grabs the kenaf stems keeping them upright and guides them towards the cutter and subsequently guides the stems backwards after cutting. The gathering system can grab stems within the harvester effective cutting width of 98cm in every single pass. After cutting they also serve as a conveyor which then off-loads the harvested stems behind the harvester. The gathering system obtains its operating power from the tractor hydraulic system which drives the grabbing fingers through a mild steel shaft by means of chain and sprocket.

Experimental Setup:

Taman Pertanian Universiti (TPU) INTROP research field

Harvesting of the Kenaf V36 and Fh 952 varieties was done at 12 - 16 weeks after sowing on an 8×3.5 m^2 research plots with 0.10 m intercrop spacing and 0.30 m row spacing manually planted with an average yield of about 76.80 t/ha for Fh 952 and 77.03t/ha for V36 in Taman Pertanian Universiti (TPU) INTROP research field. The maximum plant height recorded was 310 cm and the lowest was 150 cm. maximum stem diameter was 30mm and the smallest was 14mm. The moisture contents were determined by oven dry method at 104^0 C for 24 hours [18, 19]. The moisture contents determined ranged between 73-75% (wet basis) at harvest. The harvester was evaluated at seven harvesting speeds in order to determine and suggest an optimum and appropriate speed range for the harvester. To determine this, the harvesting speed and the travel time were noted for pre-marked 10 m distance of the field. This was done based on the existing tractor gears. Before the commencement of the field test, the field dimensions were measured using a measuring tape. The cutting height was adjusted to about 10 cm from the ground level with the tractor hydraulic system. The total time which includes both productive and non-productive times were measured using a stop watch so as to calculate the field capacity and efficiency. Total non-productive time in this regard refers to stops for equipment servicing (cleaning, troubleshooting, and adjustments), and turning time at the end of fields. To determine the effective material and field capacities, whole kenaf stems were harvested and weighed when operating at the specified speeds mention.

Field Capacity Tests

Field capacity (FC) (effective and theoretical) and field efficiency (FE) [20] are the primary parameters used to evaluate machinery performance. While FC represents the area of land processed per unit time for a particular field operation, FE is defined as the ratio between effective and theoretical field capacities and relates the estimated and actual time required to complete a field operation (with no reference to the area) [21]. Measurements or estimates of machine capacities are used to schedule field operations, power units, and labour, and to estimate machine operating costs [22]. No farm machinery is used for productive work consistently all the time. Time spent making field adjustments and repairs, adding seed, fertilizer, chemicals, water, and turning at field ends is lost as unproductive time and reduces machine capacity [23].
Theoretical field capacity (TFC) depends only on the full operating width of the machine and the average travel speed in the field. It represents the maximum possible field capacity that can be obtained at the given field speed when the effective operating width of the machine is being used. It can be calculated from equation (1) [22, 23]:

$$TFC = \frac{W x S}{10} \quad 1$$

Where:
TFC = Theoretical field capacity (ha/h)
W = Effective harvesting width (m)
S = Forward speed (km/h)

A machine cannot maintain its TFC for very long periods of time. The ratio of actual or effective field capacity (EFC) to TFC is called the machine’s field efficiency (FE).
Field efficiency is expressed as the percentage of a machine’s TFC actually achieved under real conditions. It accounts for failure to utilize the full operating width of the machine (overlapping) and many other time delays. These might include turning, idle travel across headlands or to wagons, filling seed and pesticide hoppers, emptying grain tanks, cleaning a plugged machine, checking a machine’s performance and making adjustments, and waiting for wagons and operator rest stops. Delay activities that occur outside the field, such as daily service, travel to and from the field and major repairs, and are not included in a field efficiency measurement [22, 24].It is calculated by using equation 2

$$FE\ (\%) = \frac{TFC}{EFC} \quad 2$$

Where:

FE = Field efficiency (%)
EFC = Effective field capacity (ha/h)
TFC = Theoretical field capacity (ha/h)
Conversely, if you need to estimate a machine’s EFC and have an estimate of FE, equation (3) is used.

$$EFC = TFCxFE\ (\%) \quad 3$$

The working capacity of harvesting machines is often measured by the quantity of material harvested per hour. This capacity is called the machine’s material capacity (MC), expressed as bushels per hour or tons per hour. It is the product of the machine’s EFC and the average yield of crop per hectare, and can be calculated from equation (4). [24].

$$MC = EFCxY \quad 4$$

Where:

MC = Machine’s Material capacity, (t/h)
EFC = Effective Field Capacity (ha/h)
Y = Crop Yield (t/ha)

Soil moisture content determination

A test specimen is dried in an oven at a temperature of 110°C to a constant mass. The loss of mass due to drying is considered to be water. The water content is calculated using the mass of water and the mass of the dry specimen [25].
It can therefore be calculated using equation 5.

$$W = \frac{(Mcws - Mcs)}{(Mcs - Mc)} x\ 100 = \frac{Mw}{Ms} x\ 100 \qquad 5$$

Where:
W = Water content (%)
Mcws = Mass of container and wet specimen (g)
Mcs = Mass of container and oven dry specimen (g)
Mc = Mass of container (g)
Mw = Mass of water (g)
Ms = Mass of solid particles (g)

RESULTS AND DISCUSSIONS

Taman Pertanian Universiti (TPU) INTROP research field

The field condition data for the performance tests are presented in Table 2. The tests were conducted on a flat planting system. The row spacing and the intercrop spacing were 0.30 m and 0.10 m respectively. Summary of the performance of the kenaf harvester is presented in table 3.

Table 2: Crop and field characteristics prevailing during kenaf harvesting tests

parameters		
Kenaf cultivar	Fh 952	V36
Age of plants (weeks)	12 - 16	12 - 16
Row spacing (m)	0.30 x 0.10	0.30 x 0.10
Average number of stems in 1 row	160 - 200	100 - 200
Plant population on the field (plants/ha)	715,000	715,000
Approximate yield of kenaf stem (t/ha)	76.80	77.03
Maximum height of kenaf stem above the ground surface (m).	3 - 4	3 - 4
Average cutting height of kenaf stem above the ground surface (cm).	15	15
Average moisture content of kenaf stems at harvest time (%)wb	74	61.3
Average diameter of kenaf stems (mm).	14.32	22.98
Average soil moisture content at the time of harvest (%)	30.20	29.14

At the time of harvest, appropriate yield of kenaf stem (ton/ha) was slightly different among the two varieties, while maximum plant height was uniform (3-4m). with the cutting height of stem set at 15cm above the ground level, and other crop parameters set equal and the average moisture contents varied between 74.0 and 61.3% for Fh 956 and V36 respectively and average stem diameter significantly higher in V36 (22.98mm) than Fh 952 (14.32mm), this may possiblybe a source of variation in machine capacities for both varieties.

Effect of variety on the machine capacity

The effect of variety on the machine capacity was recorded as shown in figs. 2&3. The varieties behaved differently under same harvesting conditions with resultant increase in machine capacity from 91.52 to 282.81t/day in Fh 952 while the increase was from 91.80 to 283.66 in V36. Correlation analysis on the effect on machine capacity indicated a positive high correlation of 0.90 showing significant contribution of variety to the machine capacity.

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Effects of speed on effective field capacity

The effects of tractor forward speeds on the effective field capacity indicated that increasing the speed from 2.0 to 7.7 km/h increased the effective field capacity from 1.19 to 3.68 ha/day (fig.4). This is in agreement with similar studies conducted on rice and wheat by[26 - 28].

Effects of speed on field efficiency

The effects of tractor forward speeds on the field efficiency revealed that by increasing the forward speed from 2.0 to 7.7 km/h, there was a decrease in the efficiency from 76 to 61%. The highest efficiency was recorded at 3.7 km/h and the lowest was recorded at 7.7 km/h (fig. 5).

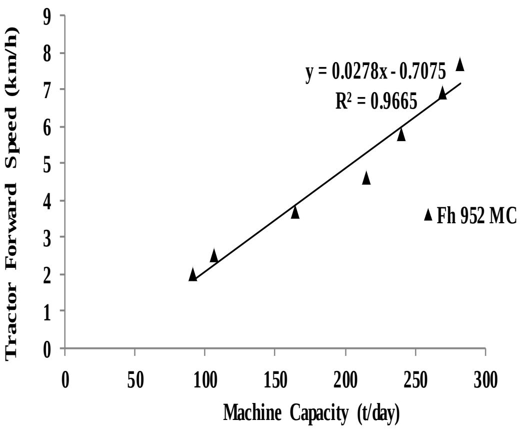

Fig. 2: Effect of Fh 952 variety on machine capacity

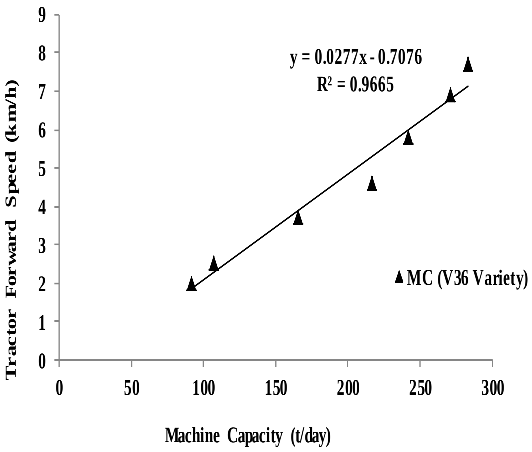

Fig. 3: Effect of V 36 variety on machine capacity

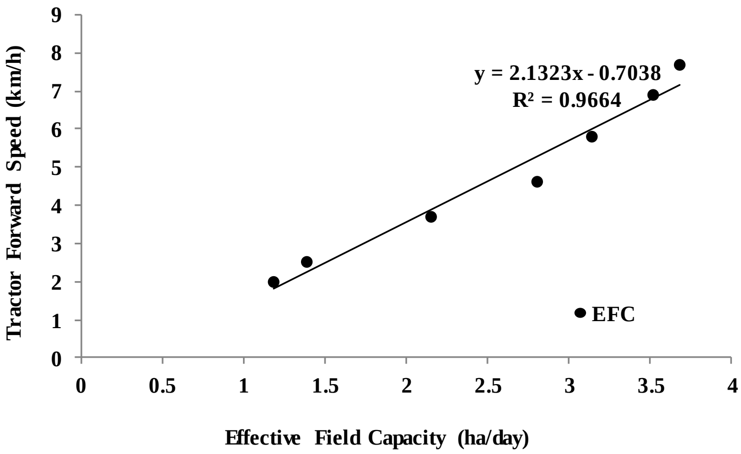

Fig. 4: Effect of speed on effective field capacity

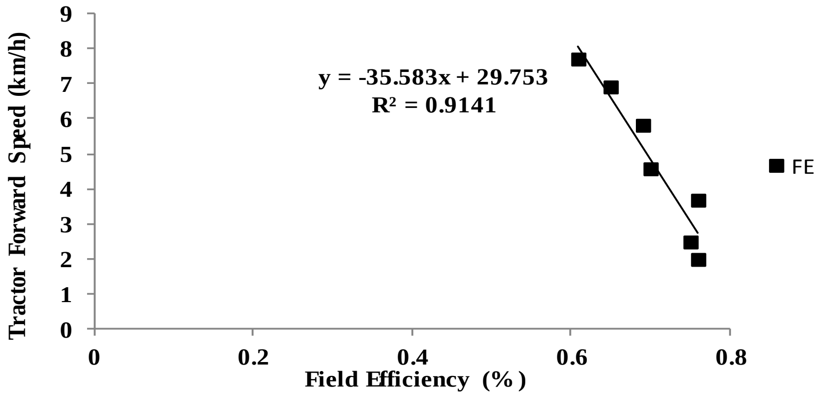

Fig. 5: Effect of speed on field efficiency

Table 3: Harvester Performance (8hrs/day)

Tractor forward speed (km/h)	***TFC (ha/day)***	***EFC (ha/day)***	***FE (%)***	***MC (t/day) Fh 952***	***MC (t/day) V36***
2.0	1.57	1.19	76	91.52	91.8
2.5	1.96	1.39	75	106.87	107.19
3.7	2.90	2.15	76	164.86	165.35
4.6	3.61	2.81	70	216.04	216.68
5.8	4.55	3.14	69	240.97	270.86
6.9	5.41	3.52	65	270.05	317.06
7.7	6.04	3.68	61	282.81	283.66

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CONCLUSIONS

A broadcast/row planted kenaf harvester has been evaluated based onseven tractor speeds.The tractor speed was found to have great influence on the performance of the harvester. The non-uniformity in diameter and height of the kenaf stems also greatly influenced the performance of the machine. Similarly, varietal difference had some effect on the machine capacity.

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REFERENCES

[1] Bakhtiari, M. R., Ahmad, D., Othman, J., and Ismail, N. (2011). Physical and Mechanical Properties of Kenaf Seed. *Transactions of the ASABE, 27*(2), 263-268.

[2] Mazumder, B. B., Nakgawa-izumi, A., Kuroda, K.-i., Ohtani, Y., and Sameshima, K. (2005). Evaluation of harvesting time effects on kenaf bast lignin by pyrolysis-gas chromatography. *Industrial Crops and Products, 21*(1), 17-24. doi: 10.1016/j.indcrop.2003.12.003

[3] Ghahraei, O., Ahmad, D., Khalina, A., Suryanto, H., and Othman, J. (2011). Cutting tests of kenaf stems. *Transactions of the ASABE, 54*(1), 51-56.

[4] Hossain, M. D., Hanafi, M. M., Jol, H., and Hazandy, A. H. (2011). Growth, yield and fiber morphology of kenaf (Hibiscus cannabinus L.) grown on sandy bris soil as influenced by different levels of carbon. *African Journal of Biotechnology 10*(50), 10087-10094.

[5] Lam, T. B. T., Hori, K., and Liyama, K. (2003). Structural characteristics of cell walls of kenaf (Hisbiscus cannabinus L) and fixation of carbon dioxide. *Journal of wood science, 49*, 255-261.

[6] Abdul Khalil, H. P. S., Yusra, A. F. I., Bhat, A. H., and Jawaid, M. (2010). Cell wall ultrastructure, anatomy, lignin distribution, and chemical composition of Malaysian cultivated kenaf fiber. *Industrial Crops and Products, 31*(1), 113-121.

[7] Tahir, M. P., Amel, B. A., Syeed, O. A. S., and Zakiah, A. (2011). Retting process of some bast plant fibers and its effect on fiber quality: A review. *Bioresources, 6*(4), 5260-5281.

[8] Jonoobi, M., Harun, J., Tahir, P. M., Shakeri, A., SaifulAzry, S., and Makinejad, M. D. (2011). Physicochemical characterization of pulp and nanofibers from kenaf stem. *Materials Letters, 65*(7), 1098-1100.

[9] Saha, A. R., Maitra, D. N., Majumdar, B., Saha, S., and Chowdhury, H. (2010). Response of kenaf (Hibiscus canabinus) to integrated nutrient management in relation to its fibre productivity, nutrient uptake and soil properties. *Irulian Journal of Agricultural Sciences 80* (2), 146-150.

[10] Jonathan, Y. C., and Frank, L. (2010). Bast Fibres: From Plants to Products *CAB International. Industrial Crops and Uses (ed. Bharat P. Singh).*

[11] Juliana, A. H., Paridah, M. T., and Anwar, U. M. K. (2012). Properties of three-layer particleboards made from kenaf (Hibiscus cannabinus L.) and rubberwood (Hevea brasiliensis). *Materials & Design, 40*(0), 59-63.

[12] Juliana, A. H., Paridah, M. T., Rahim, S., Nor Azowa, I., and Anwar, U. M. K. (2012). Properties of particleboard made from kenaf (Hibiscus cannabinus L.) as function of particle geometry. *Materials & Design, 34*(0), 406-411.

[13] Kobayashi, Y., Otsuka, K., Taniwaki, K., Sugimoto, M., and Kobayashi, K. (2003). Development of Kenaf harvesting technology using a modified sugarcane harvester. *Japan Agricultural Research Quarterly, 37*(1), 65-69.

[14] Webber III, C. L., Bledsoe, V. K., Bledsoe, R. E., Janick, J., and Whipkey, A. (2002). Kenaf harvesting and processing. *Trend in new crops and new uses*.

[15] Webber III, C. L., and Bledsoe, R. E. (1993). Kenaf: Production, harvesting, processing, and products. *New crops. John Wiley & Sons, New York*, 416-421.

[16] Kemble, L., Krishnan, P., Henning, K., & Tilmon, H. (2002). Development and evaluation of kenaf harvesting technology. *Biosystems Engineering, 81*(1), 49-56.

[17] Charles, L. W. I., Venita, K. B., and Robert, E. B. (2002). Kenaf harvesting and processing. *Trends in new crops and new uses. Janick J. and Whipkey A. (eds.). ASHS Press, Alexandria, VA.*

[18] ASABE, A. (2008). S358. 2–moisture measurement–forages, ASABE Standards, 608, American Society of Agricultural and Biological Engineers, St. *Joseph, MI*.
[19] ASABE. (2012). Adjusting Forage Harvester Test Data for Varying Crop Moisture.
[20] ASABE. (2008). Uniform Terminology for Agricultural Machinery Management. ASABE Standards, 49th edn. S495.1 NOV2005. . *ASABE, St. Joseph, MI.*
[21] Viacheslav, I. A., Robert, G., and Michael, F. K. (2011). Spatial Variability of Field Machinery Use and Efficiency. *Nutrient Management for Energy Efficiency, D. E. Clay and J. F. Shanahan, eds. , 2,* 135-146.
[22] Hunt, D. (2001). *Farm power and machinery management*: Wiley-Blackwell.
[23] Renoll, E. (1981). Predicting machine field capacity for specific field and operating conditions. *Transactions of the ASAE, 24*(1), 45-47.
[24] Hanna, M. (2002). Estimating the field capacity of farm machines. *Net, Iowa. Disponível em:< http://www. extension. iastate. edu/agdm/crops/pdf/a3-24. pdf>. Acesso em, 17*.
[25] ASTM. (1998). *Standard Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass*.
[26] Helmy, M., Fouda, T., Derbala, A. and Kassem, H., (2010). Developing the transmission system of the combine cutting device for harvesting rice crop. Misr J. Ag. Eng., 27(2): 426-437.
[27] Ismail, Z. and Abdel-Mageed, A., (2010). Workability and machinery performance for wheat harvesting. Misr J. Ag. Eng., 27(1): 90-103.
[28] Abo El-Naga, M.H.M., Shetawy, M.A.E.-S. and Abed El-Hameed, S.F., (2010). Evaluating the performance of a locally combine for harvest wheat crop. Misr J. Ag. Eng., 27(1): 104-121.