UNIVERSITI PUTRA MALAYSIA

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By

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Chairman: Professor Desa Ahmad, PhD, P. Eng.

Faculty: Engineering

This thesis describes a study on the design, fabrication and testing of a prototype sweet potato digging device for harvesting sweet potato tubers in bris soil. Design of the digging device was based on a soil bin study having bris soil with mean moisture content of 9.16% wet basis. The soil texture was sandy soil (fine sand 94.53%), and the mean bulk density of soil was 1.44 g-cm^{-3}. Three types of soil digging tools were designed and fabricated to determine the optimum draft force. These were plane, V-shaped and Hoe type blades. Plane and V-shaped blades were 30 cm long, and 13 cm wide, while the Hoe type had three rods, 25 mm diameter, 30 cm long and 6.5 cm wide with sharp cutting edge. The digging tools were tested in a soil bin filled with bris soil to determine the optimum draft force. The experiments were conducted at three depths and rake angles. All experiments were replicated three times at a constant speed of 0.06 m.s^{-1}. The results from this study were analysed and the best type was selected, fabricated and used as the prototype harvesting device.

Analysis of variance (ANOVA) for all blade types and rake angle show that, there were no significant differences between blade type and rake angle on draft force, vertical force, moment and area of soil disturbance. Comparison between all blade

types and blade depths to measured draft force and area of soil disturbance showed that the highest draft of 0.54 kN was caused by plane blade at the optimum depth of 20 cm with 0.180 m^2 of soil disturbance area. The V- shaped blade had the mean draft of 0.51 kN at the optimum depth of 20 cm. The area of soil disturbance was 0.185 m^2. The best choice was V-shaped blade with rake angle of 30^o at depth of 20 cm. The hoe-type tool had a mean draft of 0.34 kN and soil disturbance area of 0.184 m^2. The hoe-type was not selected because of excessive damage to tubers.

Based on the above information a double row sweet potato harvesting device was designed and developed. The machine was designed and developed at the Mechanization and Automation Centre, Malaysian Agricultural and Development Research Institute (MARDI) workshop. The machine consists of digger blades, double disc coulter for cutting vines, digger blade guide, and adjustable drum for blade digger depth control during operation, conveyor lifter, conveyor separator and bucket collector. Digging blade depth is adjustable with common hand tools. The harvester was designed to be pulled by Standard Four–wheel tractor of 70 HP or larger. The tractor power requirement was estimated by Algorithm analysis and tool draft force predicted by Hettiaratchi and Reece's model. Under normal operation, the machine requires three persons; one tractor driver and labourers on the harvester platform to collect the sweet potato tubers. The machine was tested on bris soil at Mardi Station, Telong, Kelantan. The digger blade was set at 35 cm depth since the average tuber zone depth was 30 cm, tractor engine speed between 1700 – 2000 rpm and PTO speed setting at 540 rpm during operation. The mean effective work of the machine in bris soil was 93.64 and 90.49% for Telong and VitAto varieties respectively. The average ground speed and turning time during operation was 0.56

km-hr^{-1} and 102.7 s and 0.99 km-hr^{-1} and 81.22 s for plots A and B respectively. The different results in tractor speed and turning for both plots were due to the different drivers operating the prototype machines. Other factors include the difference of plot size. Plot A had 50 m long seedbed while Plot B, 70 m. The harvesting efficiencies for both plots were above 90% and show no significant difference. The total productive time (harvesting time) and unproductive time (turning time) in plot A, with tractor speed 0.56 km-hr^{-1}, was 14.8 hours for harvesting a hectare of sweet potato (0.068 ha-hr^{-1}). In plot B, the total time for harvesting a hectare of sweet potato was 8.35 hours (0.12 ha-hr^{-1}) with tractor speed of 0.99 km-hr^{-1}. The average harvesting time for both plots was 11.47 hr- ha^{-1}. The average field work rate was 0.087 ha-hr^{-1} or 34 man-hr-ha^{-1} compared to manual harvesting of 150 man hr-ha^{-1}.

MEREKABENTUK DAN MEMBINA SEBUAH PERANTI PENGGALI UNTUK PENUAIAN KELEDEK

Oleh

MD. AKHIR BIN HAMID

October 2010

Pengerusi : Professor Desa Ahmad, PhD, P. Eng.

Fakulti : Kejuruteraan

Tesis ini menghuraikan kajian rekabentuk, pembangunan dan mengujiguna keatas peranti penggali, mesin penuaian ubi keledek ditanah bris. Tiga jenis peranti penggali diuji didalam kotak berisi tanah bris yang mempunyai kelembapan purata 9.16% pengkalan basah. Tekstur tanah adalah berpasir (pasir halus 94.53%), dan berketumpatan purata 1.44 g-cm^{-3}, Tiga jenis peranti penggali digunakan dalam kajian adalah; jenis kepingan, jenis berbentuk V dan jenis hoe. Lebar mata pengorek bagi jenis kepingan rata dan berbentuk V adalah 13 cm dan panjangnya adalah 30 cm. Peranti jenis hoe mempunyai tiga batang besi 30 cm panjang dan bergaris pusat 25 mm dengan bahagian hujung pemotong yang tajam. Jarak diantara batang adalah 6.5 cm dan dipatrikan berbentuk cangkol bermata tiga. Ketiga-tiga jenis peranti penggali ini diuji dalam kotak tanah berisi tanah bris bagi menentukan daya tarikan yang optimum. Percubaan dilakukan pada tiga tahap kedalaman dan sudut tusukan. Semua ujikaji diulang sebanyak tiga kali pada kelajuan malar 0.06 ms^{-1}. Keputusan jenis penggali yang terbaik dipilih untuk digunakan dalam rekabentuk prototaip mesin penuai keledek.

Analisis varians (ANOVA) untuk semua jenis peranti penggali dan sudut tusukan menunjukkan bahawa, tidak ada perbezaan yang signifikan antara jenis peranti penggali dan sudut tusukan peranti penggali keatas daya tarikan, daya menegak, momen dan luas kawasan gangguan tanah. Perbandingan antara semua jenis peranti pengorek dan kedalamanya menunjukkan peranti pengorek jenis kepingan menghasilkan daya draft tertinggi 0.54 kN pada kedalaman 20 cm dan keluasan tanah terganggu adalah 0.180 m^2. Peranti pengorek berbentuk V menghasilkan min daya tarikan sebanyak 0.51 kN pada ke dalaman 20 cm dengan keluasan tanah terganggu 0.185 m^2. Peranti bentuk V dengan sudut 30^o dipilih dalam rekabentuk mesin penuai ubi keledek. Peranti berbentuk cangkol bermata tiga (hoe) mempunyai purata draft 0.34 kN dan 0.184 m^2 keluasan tanah terganggu. Walaupun peranti jenis ini mempunyai mean daya tarikan terendah, tetapi ianya tidak dipilih kerana bentuk pecahan tanah yang mendorong kerosakan yang tinggi pada ubi ketika beroperasi.

Berdasarkan maklumat di atas sebuah mesin penuai ubi keledek telah di bangunkan. Mesin ini adalah ubahsuaian mesin pengorek kentang. Ianya dibangunkan di Pusat Mekanisasi dan Automasi, Institut Penyelidikana dan Pembangunan Pertanian Malaysia (MARDI) Workshop. Mesin terdiri dari peranti penggali bentuk V, dua piring Coulter untuk memotong lebihan jalaran tanaman, serta mengawal arah pergerakkan peranti penggali, drum kawalan kedalaman peranti penggali selama operasi, konveyor pengangkat, konveyor pemisah dan bakul pemungut ubi. Peranti penggali boleh disuaikan pada kedalaman tertentu. Mesin penuai ubi keledek ini direka untuk ditarik oleh traktor empat roda 70 HP atau lebih besar. Keperluan kuasa traktor dianggarkan melalui Algorithm analisis dan daya tarikan model Hettiaratchi dan Reece. Dalam operasi biasa, mesin memerlukan tiga orang, satu pemandu traktor dan lainnya pekerja berdiri pada platform mesin sambil memungut dan mengumpul

ubi. Mesin diuji di tanah bris di Mardi Station, Telong, Kelantan. Peranti penggali ditetapkan pada 35cm kedalaman, purata zon kedalaman ubi ialah 30 cm, kelajuan engine traktor pada kedudukan antara 1700-2000 rpm dimana PTO di setkan pada 540 rpm semasa operasi. Keputusan dari ujian mesin menunjukan purata keberkesanan kerja mesin di tanah bris adalah 93.64 dan 90.49% untuk keledek variti Telong dan VitAto. Purata kelajuan panduan trektor dan masa pusingan semasa pertukaran batas adalah 0.56 km jam $^{-1}$ dan 102.7 s dan 0.99 km-jam^{-1} dan 81.22 s untuk plot A dan B setiap satu. Kelajuan pemanduan traktor berbeza bagi setiap plot kerana pemandu yang berbeza mengendalikan prototaip mesin penuai keledek. Faktor-faktor lain termasuklah perbezaan saiz plot. Plot A 50 m panjang sementara Plot B, 70 m. Kecekapan penuaian untuk kedua plot melebihi 90% dan tidak menunjukkan perbezaan yang signifikan. Jumlah masa produktif dan tidak produktif di plot A dengan traktor kelajuan 0.56 km-jam$^{-1,}$ adalah 14.8 jam untuk menuai satu hektar ubi keledek (0.068 ha-jam^{-1}) manakala plot B, jumlah masa untuk menuai satu hektar ubi keledek adalah 8.35 jam (0.12 ha-jam^{-1}) dengan kelajuan traktor 0.99 km-jam^{-1}. Purata masa penuaian untuk kedua-dua plot adalah 11.47 jam-ha^{-1}. Purata kadar kerja diladang adalah 0.087 ha-jam^{-1} bersamaan 34 orang-jam-ha^{-1} berbanding dengan penuaian secara manual 150 jam-ha^{-1}.

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I certify that a Thesis Examination Committee has met on 14th October 2010 to conduct the final examination of Md. Akhir bin Hamid on his thesis entitled "Design and Development of A Sweet potato Digging Device" in accordance with Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The committee recommends that the student be awarded the Doctor of Philosophy.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirements for the degree of Doctor of Philosophy. The Members of the Supervisory Committee were as follows:

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DECLARATION

I declare that the thesis is based on my original work except for quotations and citations that have been duly acknowledged. I also declare that it has not been previously, and not concurrently, submitted for any other degree at Universiti Putra Malaysia or any other institution.

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MD. AKHIR BIN HAMID

Date: 14 October 2010

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