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Research Paper

Framework to develop the mechanisation of date palm cultivation

Ahmad Mostaan

Mechanisation and Postharvest Department, Date Palm and Tropical Fruits Research Institute, Ahwaz, Iran

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The trends in the mechanisation of date palm production were reviewed and five key obstacles were identified: structural heterogeneity, impact of economic and social factors, changing nature of production cycle, lack of innovation in crown access, and the lack of mechanisation indices. A general date palm mechanisation framework was developed which could help understanding and studying the obstacles to mechanisation and derive factors through the principal concepts of revenue loss and availability of the skilled palm-tree climbing workers. Increasing the rate of operation rate with fewer workers would advance date palm production. This trend could be encouraged through lower machinery costs and higher worker safety. Potential advantages of ground-based mechanisation methods are presented through analytical formulation of crown access methods. The ground-based approach appears to be more efficient than conventional approaches using palm climbing or elevating because it simplifies the three-dimensional nature of the working environment into less complex two dimensions. Ground-based methods have limitations due to the increased difficulty of operating in crown zone with increasing palm height. An operational index was defined to help develop the mechanisation of date palm cultivation. The index can reveal the height limits affordability for any date palm mechanisation systems. For each specific mechanisation operation there could be a minimum or maximum height limit and/or a height gap.

1. Introduction

Despite recent change in nutritional habits date palm, as old as mankind's history and one of the early food resources in the Middle East, still has an important role to play in the economy, food chain, and culture of these communities. Date palm cultivation worldwide has increased with significant rate in last three decades (Fig. 1) with more than 7.5 million tonnes of date fruits produced from approximately 1.1 million ha in 2012 (FAOSTAT, 2015). Dates are important fruit and food in more than 30 countries (Shamsi, 1998) with a majority of dates mainly being produced in Middle East and North Africa.

Date palm produces a remarkable high sugar fruit, with >70% average sugar content. It is known as a compact food with high and rapidly releasable energy, dietary fibre and a number of important micronutrients. However, its role in food categories (as a fruit, food or sweet) is unclear and it has a high price, mainly due to labour costs which has limited its cultivation in recent years (Mostaan, Garshasbi, Golshan Tafti, & Mosavi, 2011) as shown in Fig. 1.

E-mail address: ahmadmostaan@yahoo.com.
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Nomenclature

BH_L	Boundary low height (m)
BH_H	Boundary high height (m)
C_D	Total cost of delay in operation for the entire of an orchard (US $)
C_d	Cost of delay in operation (US $ palm^{-1})
C_{Dm}	Delay included total operational cost of mechanised method for the entire of an orchard (US $)
C_{Dt}	Delay included total operational cost of traditional method for the entire of an orchard (US $)
C_e	Cost of equipment (US $ day^{-1})
C_{eg}	Cost of equipment in GA approach (US $ day^{-1})
C_{ep}	Cost of equipment in PE approach (US $ day^{-1})
C_{GA}	Cost of operation through ground-based crown access approach (US $ palm^{-1})
C_{om}	Operational cost for elevation type mechanisation methods (US $ palm^{-1})
C_{ot}	Operational cost for traditional methods (US $ palm^{-1})
C_{PE}	Cost of operation through powered worker elevating approach (US $ palm^{-1})
C_{TC}	Cost of operation through traditional palm climbing approach (US $ palm^{-1})
C_{wg}	Cost of an individual GA approach worker (US $ palm^{-1})
C_{wm}	Cost of an individual mechanised system worker (US $ palm^{-1})
C_{wp}	Cost of an individual PE approach worker (US $ palm^{-1})
C_{wt}	Cost of an individual traditional system worker (US $ palm^{-1})
c_{ct}	Time conversion coefficient (= 8 assuming an effective 8 h for a working day)
c_h	Operation time compensation factor (dimensionless, rationally <0.1)
cp	Execution of the required cultural practice
c_{rl}	Revenue loss factor (dimensionless, rationally <0.1)
d	Delay time of operation (d)
d_a	Actual delay time (d)
d_u	Ultimate tolerable delay time (d)
h	Working height (m)
GA	Ground based crown access approach
GMF	General mechanisation framework
MHG	Mechanisation height gap (m)
MDP	Mechanisation decision point (m)
MSW	Mechanised system worker
mh	Horizontal movement
vm	Vertical movement
N	Total number of the orchard palms (count)
n_h	Number of palms having equal height of h (count)
n_x	Number of palms having equal height of x (count)
n_{wa}	Available number of workers hired in the operation crew (count)
n_{wg}	Number of workers in GA approach operating crew (count)
n_{wm}	Number of workers in the mechanised operating crew (count)
n_{wp}	Number of workers in PE approach operating crew (count)
n_{wr}	Minimum number of required workers in the operational crew (count)
n_{wt}	Number of workers in traditional operating crew (count)
P	Product price (US $ kg^{-1})
PE	Powered worker elevation approach
R_a	Actual rate of operation (palm d^{-1})
R_m	Operating rate in mechanised methods (palm d^{-1})
RLF	Revenue loss factor
R_{min}	Minimum rate of operation (palm d $^{-1}$)
R_{oh}	Operating rate of the method for palms of same working height of h (palm h^{-1})
R_{ox}	Operating rate of the method for palms of same working height x (palm h^{-1})
R_t	Operating rate using traditional methods (palm d^{-1})
r_o	Convenient operating rate of the palm worker (palm d^{-1})
SPW	Skilled palm climbing worker
t_o	Total time of operation (h palm^{-1})
TC	Traditional palm climbing approach
t_{cp}	Time of execution of the desired cultural practice (h palm^{-1})
t_{cp0}	Time of execution of the desired cultural practice at height of zero (h palm^{-1})
t_{cpg}	Time of execution of the desired cultural practice in GA approach (h palm^{-1})
t_{cpp}	Time of execution of the desired cultural practice in PE approach (h palm^{-1})
t_{cpt}	Time of execution of the desired cultural practice in TC approach (h palm^{-1})
t_{cpx}	Time of execution of the desired cultural practice at height of x (h palm^{-1})
t_h	Total time of operation for the entire of palms with working height h (h)
t_{mh}	Time of horizontal movement (h palm^{-1})
t_{mhg}	Time of horizontal movement in GA approach (h palm^{-1})
t_{mhp}	Time of horizontal movement in PE approach (h palm^{-1})
t_{mht}	Time of horizontal movement in TC approach (h palm^{-1})
t_{mv}	Time of vertical movement (h palm^{-1})
t_{mvg}	Time of vertical movement in GA approach (h palm^{-1})
t_{mvp}	Time of vertical movement in PE approach (h palm^{-1})
t_{mvt}	Time of vertical movement in TC approach (h palm^{-1})
t_t	Total time of operation for the entire of an orchard (d)
t_{tm}	Total time of mechanised operation for the entire of an orchard (d)