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SIMULATION OF CASSAVA GRATING SYSTEMS FOR COTTAGE INDUSTRIES

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ABSTRACT

The paper presents a simulation of cassava grating system. Processing of gari is a job for women but its techniques of operation have witness measures of changes in Nigeria. There exist various versions of mechanical graters that are powered either by electric motors or small internal combustion engine. This paper describes a mathematical model that simulates optimum cassava grating system for various processing cottage capacity and the power source used in the cottage industry. A computer program written in a basic language computes the appropriate size of grater for a given processing cottage capacity and the source of power required at various cost associated with grating operation; fixed cost, variable cost and timeliness cost; system's hour requirement; cost of the system and the least cost grating system. The model thus developed was tested on some selected gari processing cottage industries with varying processing cottage capacities. The cost requirement and the associated components of grating system for grating cassava at varying cottage processing capacity up to about 10 ha of crop service area was evaluated in Bida, Nigeria. The least cost involved for different system was determined.

Key words: Cassava, Simulation, Grating systems, Mathematical model, Least cost

INTRODUCTION

Gari, a granular food product from cassava, is one of the main sources of carbohydrate for more than 80 % of the inhabitants of the West African subregion (Igbeka *et al.* 1992). Cassava grating is one of the processes involved in production of Gari. Grating can either be carried out manually or mechanically with the application of grating machine. Although the manual grating is tedious, time consuming and hazardous, its level of usage still remains high.

Different forms of mechanical graters include rotating solid wood drum wrapped with serrated or punched metal plate, horizontal rotating high roughened disc held in place by a vertical shaft and designed rasper made of a series of hack saw blades fixed at intervals on a high quality poly vinyl chloride rotating drum. The average size of gari processing cottage industries vary from household level to a more established commercial centers so one type of grating system may not be suitable for all. The typical flow chart of the operations involved in processing gari is shown in Figure 1.

Traditionally, grating is done by manually rubbing the peeled roots against roughened surface, usually made of perforated 3 mm thick piece of galvanized mild steel sheet on a wooden or metal frame. Result of manual grating of cassava leads to non uniform particle sizes as well as substantial losses arising from the inability of the person to hold small pieces of cassava roots for grating. (Adjenbeng Asem, 1989). Igbeka *et al* (1992) reported that the cost of grating with the design rasper made of a series of hack saw blades is high for the average local gari producer.

Philip et al. (2004) studied to determine the actual and potential size of the market for cassava and cassava based products in Nigeria and what is required in terms of economic, social and physical investments to develop an efficient cassava industrial sector. They concluded that sustainability demands a participatory process, transparency, relevancy and cost recovery. It is suggested that each activity follows its own path starting with small modest objectives and budgets, growing only as cost recovering resources allow. Sustainability also demands ownership of change. It means participating fully and being rewarded for that participation. It means taking ownership of the problems and difficulties arising from change. Changing attitudes, consumer perception, and business practices are not easy and require patience and time and initiation from within. The Food and Agriculture Organization of the United Nations (FAO) in Rome (FAO, 2004) estimated 2002 cassava production in Nigeria to be approximately 34 million tonnes. The trend for cassava production reported by the Central Bank of Nigeria mirrored the FAO data until 1996 and thereafter rises to the highest estimate of production at 37 million tonnes in 2000 (FMANR, 1997).

Information currently available on the grating of cassava is more related to the choice and application of various types of available grater rather than design characteristics and factor of selection as related nature of application. The current practices revealed that graters are chosen either arbitrarily or by mere convenience due to what is available. This procedure failed to give due consideration for the least cost analysis associated with the use of various grating systems in term of the farm size and the capacity of the cottage industries providing the grating services to a given crop service area. Irrational approach in taking decision on selection and utilization of cassava grating systems leads to waste and ineffective application of farm machinery. Appropriate selection of farm machinery for various farm operations is an important perquisite that can lead to improvement in machinery output, timeliness of operation and reduction of unnecessary associated production cost.

According to Scott et al. (2000) and FAO

(2004) in Philips et al. (2004) they reported that research institutes, such as IFPRI and FAO suggest a more conservative production target for cassava. Extrapolating from estimates for cassava production in Africa Nigeria's production is targeted at 40 million tonnes by 2005 and 60 million tonnes by 2020 (IITA, 2002). This target relates well to the mapping of a simple linear time trend on historical production levels. It is imperative that attempt to judiciously process the product without incurring excessive waste should be exploited. Qualitative analysis and simulation of cassava grating operation is essential in the determination of the effectiveness of any given grating system with respect to farm size and capacity of the cottage industry providing the grating operation to a given crop service area. The aim of this paper is to simulate an optimum size cassava grater for a given cottage capacity and power source.

COST ASSOCIATED WITH GRATING SYSTEM

Fixed cost, variable cost and timeliness cost are various cost associated with processing operations (Hunt, 1977). This study considered various fixed cost such as depreciation, interest, insurance, taxes and shelter for various grating systems. Variable cost includes cost of fuel, oil, labour, repair and maintenance and power source cost. Timeliness cost is considered as a result of inability of the grating system to perform the operation during optimum period.

ASSUMPTIONS FOR FORMULATION OF MATHEMATICAL MODEL

The following assumed parameters were used to formulate both the conceptual and mathematical model and to develop the algorithm.

1. The cost of fuel and oil needed is directly proportional to power consumption of the source of power required to operate the grater.
2. Annual use of power source is constant for the whole life of the grating system. This value remains fixed.
3. The size of the grater determines its cost.
4. The maximum use of a grater is assumed to be 3 hour per day for 20 working days per month for 5 months in a year.
5. The size of grater is expressed in terms of unit capacity in kg/hr
6. The graters are neither insured nor subjected to taxes as importation on agricultural equipment are duty free.

DEVELOPMENT OF THE MATHEMATICAL MODEL

A mathematical model was derived for the optimum cassava grating system. The method used by Gupta. *et al* (1986) and Hunt (1977) was adapted. Derivations of mathematical models in evaluation of associated costs in using grating system were established. Annual fixed cost, annual variable cost and annual timeliness cost were associated annual cost for using grating system. Equation 1 presents fixed annual cost of the grater. The fixed cost consists of the cost of the grater as related to the unit capaci:y of the grater, salvage value factor, economic life of power source and system depreciation cost. A straight-line method was used to determine the depreciation of the grater.

$$AFC = (UCC) * (CG) * (1 - SVF) * \left(\frac{1}{EELG} + \frac{IR}{2} + \frac{SC}{2}\right) \quad (1)$$

The annual variable cost consists of all associated running costs during operation and for owning and maintaining a grater. This cost involved energy required for grating, cost of fuel (this is related to the specific fuel consumption of power source), cost of oil as related to the oil requirement of the power source (oil requirement of power source is expressed in % of fuel consumption), labour cost, repair and maintenance cost for grater as related to the price per unit capacity of grater and cost of power source.

The power cost is estimated independently before substitution into the annual variable cost Equation 3. The power source may be internal combustion engines and electric motors. For motors, the electricity charges may be considered as fixed amount if the bill is on flat rate or it may be on the basis of energy consumption, kwh. The power cost per hour is therefore estimated for any power source using equation 2.

$$PSC = (CPS) * \left(\frac{1 - (SVF)}{(EELPS)}\right) + \left(\frac{1 - (SVF)}{2}\right) + \left(\frac{(IR) + (SC) + (RIT)}{(AUPS)}\right) + \left(\frac{(RMFPS) * (CPS)}{1000}\right) + \left(\frac{(EFR) * 12 * (SPS)}{(AUPS)}\right) \quad (2)$$

The annual variable cost is given as equation 3.

$$AVC = \frac{(CPC) * (YC)}{(CG)} \left[(LCG) + \frac{(EG) * (CG)}{(EPTS)} * (SFCPS) * (CFUEL) + \frac{(EG) * (CG)}{(EPTS)} * (SFCPS) * (ORPS) * (COIL) + \frac{(RMFG) * (PUCG) * (CG)}{1000} + (PSC) \right] \quad (3)$$

Estimate of the custom work is presented by equation 4

$$WHC = \frac{((AFC) - (CPC) * (YC) * ((CRG) - (OCG)))}{((CG) * ((CRG) - (OCG)))} \quad (4)$$

Annual timeliness cost is given in equation 5.

$$ATC = \frac{(CPC) * (YC)}{(CG)} x \frac{(YLG) * (CPC) * (YC) * (PC)}{(WHDG) * 2} \quad (5)$$

The total annual cost is given in equation 6 as the summation of all the associated costs in using a given grater.

$$AC = AFC + AVC + ATC \quad (6)$$

The size of processing equipment that will meet the demand and work schedule of a given cottage capacity at least cost is presented by assuming that the differential of the annual cost with respect to the capacity of the equipment being equal to zero (Guptal *et al.*, 1986). The differential of equation 6 with respect to the grating capacity, CG that is $\frac{d(AC)}{d(CG)} = 0 = (CG)_{opt}$ gives equation 7.

$$(CG)_{opt} = \left[(CPC)*(YC)*((LCG)+(PSC)+(ULG))*(CPC)*(YC)*(PC)*\frac{(WHDG)}{2}\right]^{\frac{1}{2}} \quad (7)$$

$$*\left[(PUCG)*\frac{(1-(SVF))}{(ELG)}*(1-(SVF))*\frac{((IR)+(SC))}{2}\right]^{-\frac{1}{2}}$$

COMPUTER PROGRAM

The model presented in equation 7 indicates optimum condition for cassava grating operation at $(CG)_{opt}$. To arrive at this optimum condition, optimum values of the variables in Equation 7 must be tested and established. A computer programme (JOGS) written in QBasic was developed using equations 1 to 7. The development of the QBasic programme was based on the steps presented in the flow chat for the determination of optimum grating system (Figure 2). The program (JOGS) is to determine the optimum size of grater for a given cottage capacity to serve a crop area and power source, to compare the system cost of each grating system and to finally select the least cost grating system for different capacities of processing area. Seventeen grating systems were studied in Bida, Nigeria. The program developed was used to determine the least cost grating system.

RESULTS AND DISCUSSION

The program helps to determine when owning a grater is uneconomical especially if the variable cost is greater than the custom rate of grating. The output result for a grater with rotating solid wooden drum wrapped with punched metal plate which serves crop area of about 4 ha is presented in Table 1. Table 1 shows that for all the seventeen grating systems that were examined owning a grater is considered uneconomical. The services of the cassava grater operator could be more dependable at least cost and for optimum performance.

The results shown in Table 2 indicate that the cost of grating decreases with increasing crop area. The reason for this trend may be as a result of decrease in fixed cost of grating with increasing system hours when compared to the increase in timeliness factor. The timeliness factor increases from YLG = 0 to 0.01 as shown in Table 2. Similarly, an increase in timeliness factor revealed a corresponding increase in cost of grating for any size of cottage processing service area. Table 2 showed that a low unit cost of grating is possible where the cassava producer can generate large production that can keep the cassava grater operator on a long system hours of operation. The results also indicated that a grater service provider that opted for a small unit of cottage processing service area has the tendency to operate at initial high unit cost of grating but with possibility of operating far below operating capacity of the grating system (Table 2). The effect is under utilization of the system with high cost recorded on the overhead and operating cost.

Fig. 3 gives the different sizes of graters for various of electric motors. The results of possible optimum combination of power source and grater for given cottage processing unit that serves a given crop area is shown in Fig. 4. The system for a least grating system is also indicated.

The least cost size of grater, the power source for a given cottage unit with the crop area it serves and at three levels of timeliness cost factors for farms growing cassava up to 10 ha are the main factors that will assist in selection procedure. As a result of increase in timeliness, the size of the least cost grater as well as the power source increases. The increased size of grater compensated the timeliness cost, which is higher in the case of small size grater. Fig. 4 also shows that an increase in crop area does not always show a corresponding increase in the size of least cost grater. This is because for small farms the least cost of grater is small and the minimum size of grater is to be selected (for example, at YLG = 0) for crop area up to 2.8 ha the grater selected is 124 kg/h.

The optimum grating system was established for different crop areas. Two types of power source were considered; electric motor and internal combustion engine. The least cost is limited by available power source at YLG = 0 and for crop areas of 7 to 10 ha. The least cost of grater is 160 kg/h and this is limited by 2.7 kW motor; and for large crop areas with an increase in timeliness cost factor, the least cost size of grater is dictated by the maximum size of grater available in the market.

CONCLUSION

The program developed can be used to select an optimum grating system for a given cottage processing unit and the crop area it serves and the size of the power source it uses. It can aid in selecting the least cost grating system among many available grating system in the farm. The program developed can be used as an important tool for research and extension purposes in establishing the profitability and appropriateness of adoption of a specific form of grating system

Table 1: Out put result obtained with JOGS program

Optimum Cassava Grating Systems												
Grater type = Solid wooden drum with punched metal plate							Cottage crop area under service = 4ha					
System	NPS	SPS	CG	PG*	FCG	OCG	TCG	CPG	AUG	WHRC	SHC	SCOST
1	Engine	2.5	120	5300	2.5	4.0	0	6.5	55.5	0	55.5	518.2
2	Engine	3.7	135	5700	2.7	5.0	0	7.7	54.0	0	54.0	561.9
3	Engine	5.2	150	6900	3.2	6.6	0	9.8	53.4	0	53.4	622.1
4	Engine	6.0	165	8100	3.8	7.6	0	11.4	52.5	0	52.5	618.1
5	Engine	7.5	195	9800	4.6	9.5	0	14.0	51.4	0	51.4	706.3
6	Engine	11.2	205	11400	5.3	13.3	0	18.6	50.9	0	50.9	747.4
7	Engine	14.9	235	13500	6.3	16.0	0	23.0	49.5	0	49.5	759.4
8	Engine	18.6	250	17600	8.2	22.2	0	30.4	48.0	0	48.0	830.2
9	Motor	2.0	115	4700	2.2	3.3	0	5.5	61.5	0	61.5	485.2
10	Motor	2.7	120	5300	2.5	4.2	0	6.7	60.0	0	60.0	518.2
11	Motor	4.0	140	6200	2.9	5.5	0	8.4	58.3	0	58.3	585.8
12	Motor	6.7	165	8800	4.1	8.7	0	12.8	52.5	0	52.5	633.2
13	Motor	10.0	205	10900	5.1	12.0	0	17.1	50.9	0	50.9	740.9
14	Motor	13.5	230	12300	5.7	17.1	0	28.9	49.5	0	49.5	801.9
15	Motor	20.0	245	18700	8.7	28.9	0	32.9	48.0	0	48.0	812.9
16	Motor	26.8	275	19000	9.8	32.9	0	37.8	44.4	0	44.4	863.4
17	Motor	34.0	305	23900	11.1	37.7	0	48.8	40.5	0	40.5	944.3

* Cost of fairly used electric motor and internal combustion engine were used. Purchase of fairly used articles seems to be the demand at present in Nigeria.

Table 2: Cost of grating and systems hours of least cost threshing systems (For solid wooden drum with perforated metal plate type of grater)

Cottage Processing service area (ha)	Timeliness factor					
	YLG = 0		YLG = 0.005		YLG = 0.01	
	Cost of grating ₦ /Kg	System hour h	Cost of grating ₦ /Kg	System hour h	Cost of grating ₦ /Kg	System hour h
1	90.2	10.2	95.2	18.2	97.8	18.2
2	73.6	36.4	89.3	36.4	90.2	36.4
3	60.4	50.4	73.4	50.4	86.4	48.1
4	44.2	62.6	73.0	52.6	80.2	45.2
5	32.5	70.3	60.5	58.8	72.8	40.3
6	14.8	76.4	52.6	60.4	68.4	47.4
7	12.5	80.5	40.3	62.5	52.5	50.6
8	10.0	114.5	25.0	64.4	30.6	62.4
9	9.2	160.0	17.3	68.2	22.5	68.5
10	5.5	172.3	12.0	70.0	20.0	70.8

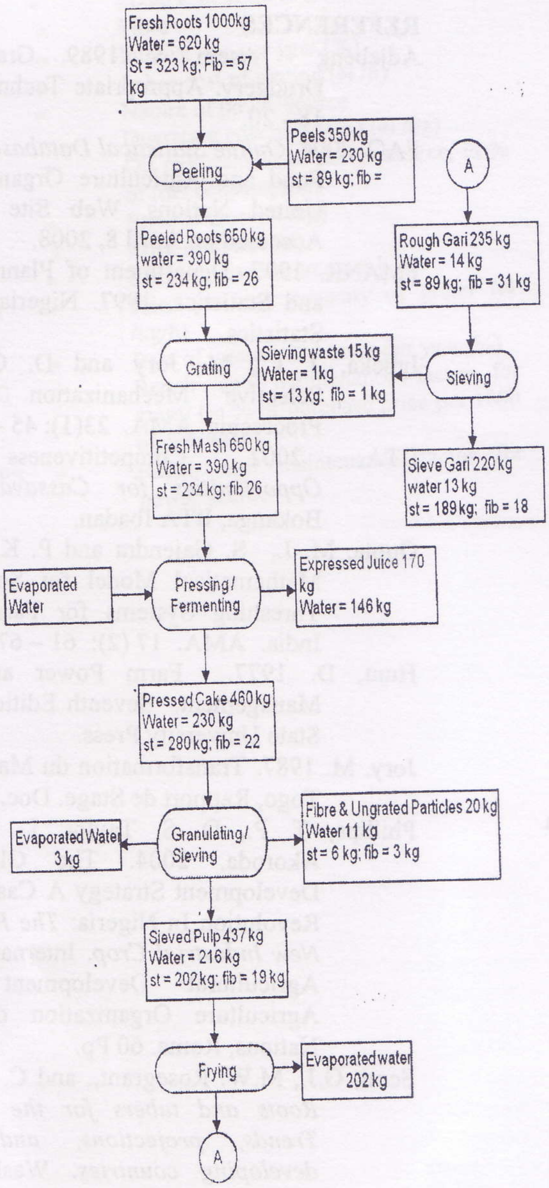

Fig. 1: Traditional Gari Processing Flow Chart (Jory, 1987)

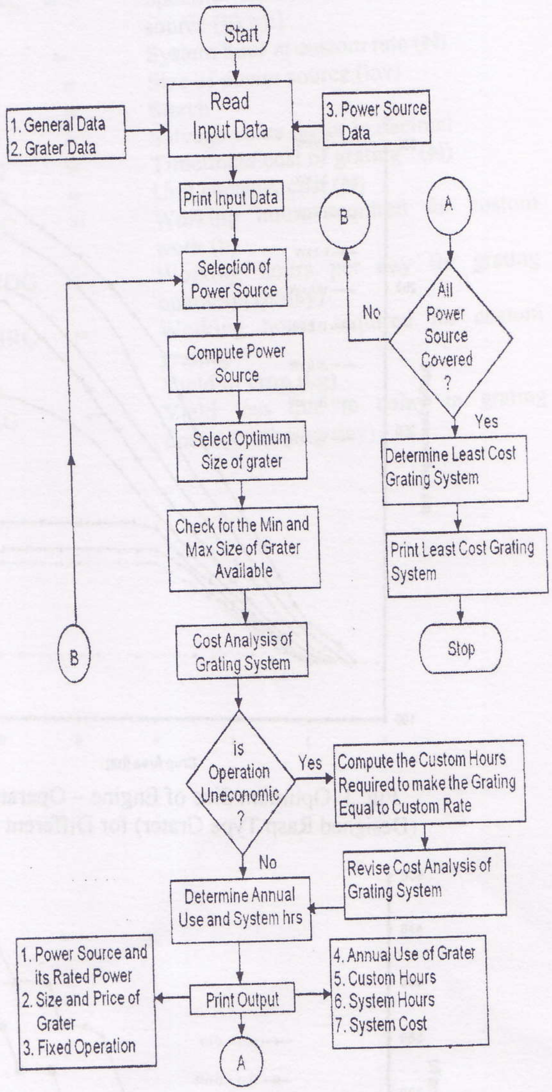

Fig. 2: Flow Chart for the Orogramme for the Determination of Optimum Grating System

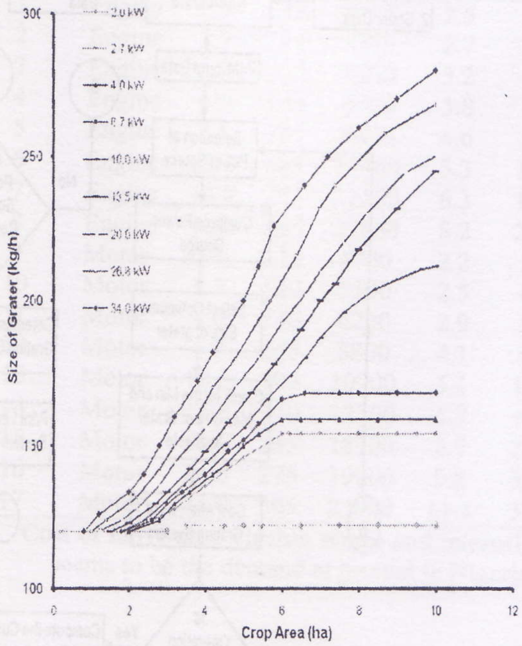

Fig. 3: Optimum Size of Engine – Operated Grater (Designed Rasp Type Grater) for Different Crop Area.

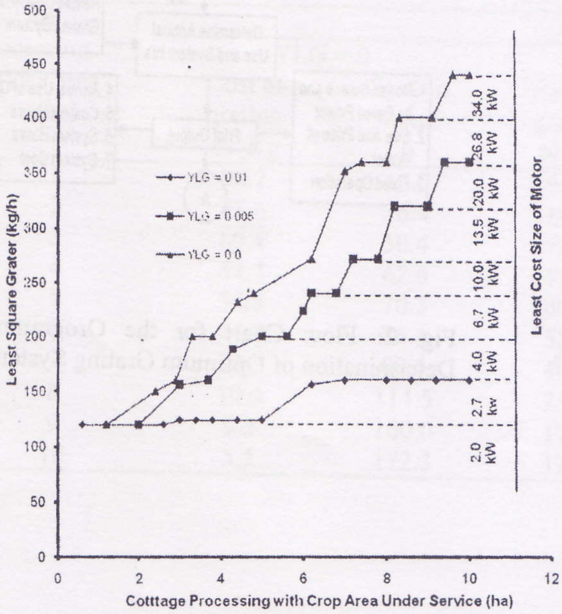

Fig. 4: Least cost Grating System (Designed Rasp Type Grater) for Farms Up to 10 Hectare.

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Fig. 4: Least cost Grating System (Designed Rasp Type Grater) for Farms up to 10 Hectare.

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NOTATIONS

AFC	=	Annual fixed cost (₦)
AUG	=	Annual use of grater
AUPS	=	Annual use of power sources (h/year)
CFUEL	=	Cost of fuel (₦ /l)
CG	=	Capacity of grater (kg/h)
COIL	=	Cost of oil (₦ /l)
CPC	=	Cottage processing service area (ha)
CPG	=	Cost price of grating (₦)
CPS	=	Cost of power source (₦ /l)
CRG	=	Custom rate of grating (₦ /kg)
EELG	=	Estimated economic life of grater in years
EELPS	=	Estimated economic life of power source in year
EFR	=	Electricity flat rate (₦/kw-month)
EG	=	Energy required for grating (kw)
EPTS	=	Efficiency of power transmission

system (%)

FCG	=	Fixed cost of grating (₦)
Fib	=	Fibre
IR	=	Interest rate per year (%)
LCG	=	Labor cost of grating (₦ /h)
NPS	=	Nature of power source
OCG	=	Operating cost of grating (₦ /kg)
ORPS	=	Oil requirement of power source, in % of fuel consumption
PC	=	Price of crop (₦ /kg)
PG	=	Price of grater (₦)
PSC	=	Cost of power source per h
PUCG	=	Price per unit capacity of grater (₦ /kg/h)
RIT	=	Rate of interest and taxes per year (%)
RMFG	=	Repair and maintenance factor for grater (in % of purchase price per 100h of operation)
RMFPS	=	Repair and maintenance factor for power source
SC	=	System depreciation cost (₦)
SCOST	=	Optimum grating system cost (₦)
SFCPS	=	Specific fuel consumption of power source (l/kwh)
SHC	=	System hour at custom rate (₦)
SPS	=	Size of power source (kw)
St	=	Starch
SVF	=	Salvage value factor in decimal
TCG	=	Timeliness cost of grating (₦)
UCC	=	Unit capacity cost (₦)
WHC	=	Working hours required for custom work (h)
WHDG	=	Working hours per day for grating operation (h/day)
WHRC	=	Working hours required for custom grating
YC	=	Yield of crop (kg)
YLG	=	Yield loss due to delay in grating operation (kg/kg-day)