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RESEARCH ARTICLE

DESIGN MODIFICATION AND FIELD TESTING OF GROUNDNUT DIGGER

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ABSTRACT

Groundnut is the major Kharief crop of Barani areas in Pakistan. Groundnut yield is the major source of income for these farmers. Groundnut is grown over 0.106 million hectares and resulting the annual yield of 77.6 thousand tons. The average yield of groundnut in Pakistan is nearly 0.88 tons/ha. Conventional diggers/pullers are used to harvest groundnut/peanuts from the soil. These diggers do not shake or invert the crop which is necessary for good threshing after sun drying. The existing digger/shaker was tested at Agricultural Mechanization Research Institute (AMRI) Wing, Jhang Road, Faisalabad. During field testing, the machine performance was found unsatisfactory. The bridging/blocking of heavy crop due to low clearance between upper supporting bars, conveyor and slippage of the peanut plants on the conveyor was also noticed. The slicing action of the blade was poor. The blade was performing shear action instead of slicing. The machine had 0.27 ha/h effective field capacity, 85.60% field efficiency, 85.40% digging efficiency, 6.50% recoverable loss and 9.50% irrecoverable loss. Keeping in view, the above problems, the necessary modifications were incorporated to improve the field efficiency of the digger. During modification, the space between the supporting bars and conveyors was optimized. The blade was divided into three continuous welded pieces, front roller was removed and small pegs were welded on the front conveyor to overcome these problems. Finally, the field test was conducted at the farms of Barani Agricultural Research Institute, Chakwal for machine evaluation. Field performance of the digger was evaluated at three maturity levels of the crop (65%, 75% and 85% matured pods), three plot sizes at three different speeds of machine. Data regarding productive, seenable and unseenable weights were collected and statistically analyzed. The best digging efficiency was 89.31% at 75% maturity level, the field efficiency was 89.31% at 1.85km/h, recoverable loss was 5.14 % at 1.85km/h and irrecoverable loss was 5.55% at 1.85km/h. The field test expressed that the AMRI groundnut digger/shaker was improved reasonably after modification. It became more fuel efficient resulting in energy saving.

INTRODUCTION

Agriculture is the backbone of Pakistan's economy as it is single major sector of the economy, which is contributing 21.8 % to GDP and employs 44.7 % of the workforce. More than two-third of Pakistan's population belongs to rural areas and their livelihood depends on agriculture (ESP, 2009). Groundnut is the major kharief crop of barani areas of Pakistan. Groundnut yield is the major source of income for farmers of these areas. Groundnut is grown on more than 0.106 million hectares providing a yield about 77.6 thousand tons annually. The average yield of groundnut in Pakistan is 0.88 tons per hectare (Anonymous, 2008). About 82.8% of total area under groundnut plantation is in Rawalpindi Division in Pakistan (Malik, 2004). Presently, the gap between demand and production of groundnut is about 1.9 million tons. Total requirement of edible oils is projected with a growth rate of 3.76% and production is projected with a growth rate of 4%. Total requirement of edible oil will be 5.36 million tons by 2030 while projected level of production is 1.98 million tons and the gap is of 3.4 million tons. Edible oils self-sufficiency may not be possible in the short run but in the long run the prospects seem reasonable (Sumia et al., 2009). This self-sufficiency can be achieved by using latest agri-machinery for groundnut production as it is major source of edible oil. Mainly, the focus must be the harvesting machinery because the main production loss is in the form of irrecoverable and recoverable loss during harvesting. The groundnut kernel is rich both in oil (43-55 %) and protein (25-28 %). Its oil contains about 22% linoleuc acid, 61% oleic acid and possesses high smoke point (USDA, 2010). The increase in import of edible oils is 6.6% per annum since 1991-92. Cottonseed contributes 51% of domestic oil production; sunflower is the second important crop contributing about

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32%, while canola, rapeseed and mustard are contributing only 17% (Anonymous, 2008). Lack of appropriate technology and efficient harvesting and extraction machinery are the important factors that contribute towards the lower productivity and inefficient extraction of edible oil. Crop losses during harvesting and extraction majorly reduce the oil production. Low productivity of oilseeds is also due to shortage of water. Yields are in the range of 15-46% of the available potential. Although, safflower, sunflower and canola are showing relatively good yield, they are still giving even less than half of their potential yield due to in-efficient production technology, lack of improved seed, inadequate water and in-efficient harvesting and extraction machinery and techniques (Ahmad et al., 2007). Harvesting of groundnut at proper time is a key factor for increased crop yields like other cash crops. Early digging results in lower maturity that considerably lowers the yield. Late digging results in more shattering losses in the soil and digging cost is also boosted up due to dry and hard soil. The optimum digging time is determined by digging some plants from the field and by counting the number matured pods. Digging allowed when 70-75% pods are matured. Crop can be dug out properly with hand tools like Khurpa, Kasola and Spade and pods may be picked up from the soil as much as possible. A tractor operated digger is also available and can be efficiently used for groundnut digging. A peanut digger was developed at Agricultural Mechanization Research Institute (AMRI) and was tested for its performance at the farms of Barani Agricultural Research Institute (BARI), Chakwal. The digger resulted unsatisfactory performance. Therefore, this study was designed to modify and redevelop AMRI groundnut digger to increase its performance under field conditions. The objectives of the study were to modify and improve the AMRI groundnut digger shaker and to perform field test to assess its performance under practical conditions.

MATERIALS AND METHODS

During the first phase of the research, modification, improvement and fabrication of different components of AMRI groundnut digger shaker was carried out while during second phase the performance evaluation of the digger was carried out. The major components of AMRI groundnut digger include 1) cutting blade, 2) front roller, 3) conveyor and 4) supporting bars. The existing AMRI groundnut digger is shown in Figure 1.

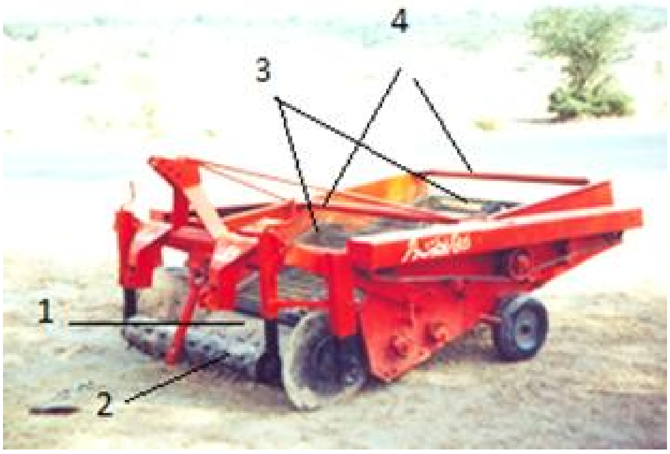

Fig. 1. Existing AMRI groundnut digger

The improvement modification and redevelopment of the following components have been carried out during the redevelopment phase of the machine.

Supporting bars

There are two supporting bars on the machine. The function of these bars is to support all the machine assembly. The clearance between the conveyor and bars was not enough to convoy thick crop. During the modification, the space was optimized. The modified supporting bars in the groundnut digger are shown in Figure 2.

Fig. 2. Modified supporting bars

Cutting blade

The cutting blade was notched and of rectangular shape. The slicing action of the blade was very poor. The modified blade was divided into three sharp blades without notches to improve the slicing of the soil. The modified form of cutting blade in the digger is shown in Figure 3.

Fig. 3. Modified cutting blade

Conveyor

The existing conveyor consisted of equally spaced bars which did not provide any gripping arrangement for peanut plants for conveying purpose. A series of small pegs at alternate positions was provided on the conveyor (Figure 4). These pegs were welded on the conveyor to minimize the crop slippage.

Front roller

Front roller is that part of the machine which was basically used for breaking of clods. It was removed during the modification, because no clods develop in sandy soil.

Fig. 4. Modified view of conveyor

Main specification of the redeveloped digger

The groundnut digger is a tractor mounted and PTO driven machine. The machine is capable of performing two functions in one operation, e.g. digging and shaking. The main specifications of redeveloped groundnut digger have been shown in Table 1 while the finally redeveloped groundnut digger is shown in Figure 5.

Table 1. Specifications of the redeveloped groundnut digger

Item	Specifications
Make	AMRI Faisalabad
Model	Tractor mounted conveyor type
Length	2540 mm
Width	1720 mm
Height	1290 mm
Width of blade	1210 mm

Fig. 5. Modified form of groundnut digger

Field performance evaluation of groundnut digger/shaker

The redeveloped groundnut digger was transported major peanut grown crop area (sandy loam soil and suitable weather for proper growth of groundnut) of Tehsil Talagang, District Chakwal. The performance of groundnut digger was carried out in terms of 1) machine field capacity, 2) machine field efficiency, 3) machine harvesting losses and 4) machine digging efficiency. Field testing of AMRI digger/shaker for different performance parameters was carried out in the experimental peanut farms of Barani Agricultural Research Institute (BARI), Chakwal. Field performance tests were also conducted in the fields of Village Dhoke Baza, 15 km Mainwali Road, Tehsil Talagang, District Chakwal. The plots of BARI were best suited to evaluate the performance of the machine, because these were maintained by recent agronomic practices, inter-culture and plant protection measures and best land leveling operations. The methodology adopted and instruments used for data collection to assess the digger performance are discussed below:

Measuring instruments

The instruments used to collect the data during the performance evaluation of the modified AMRI groundnut digger includes 1) measuring tape, 2) digital stopwatch, 3) tachometer, 4) digital balance, 5) electric oven and 6) steel rod frame (1 m long x 1 m wide).

Field layout

The experimental field was divided into three subplots measuring 100m×50m, 100m×100m and 100m×150m. The machine was operated to harvest the crop at three different levels of crop maturity M_1-65%, M_2-75% and M_3-85%. The sub-plots were further divided longitudinally into three sub-plots to perform digging at three different tractor speeds of S_1=1.52 km/h, S_2=1.85 km/h and S_3=2.13 km/h. The field pattern used for digging was circuitous from center to outwards (Wahid, 1993) to avoid repetition on the dugout area. Field shape, field dimensions and area were measured by using measuring tape. The field layout plan is shown in Figure 6.

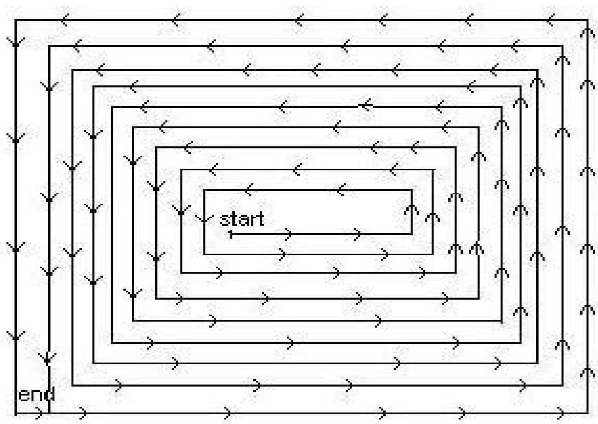

Fig. 6. Field layout plan

Statistical analysis

A 3×3×3 factor factorial was employed in RCBD statistical design to evaluate the effect of three levels of maturity, three forward speeds of digger and three field sizes on the machine efficiency and crop recovery. The statistical design RCBD was used due to scattered nature of experimental area with different sites and management practices. The statistical analysis was carried out using PROC GLM (General Linear Model) procedures of SAS Institute, version 9.1 (SAS, 2002-03).

RESULT AND DISCUSSION

The statistically analyzed results of effects of crop maturity level (ML), field size (F) and tractor/machine forward speed (S) on effective field capacity (EFC), field efficiency (FE) and digging efficiency (DE) have been discussed as follows:

Effect of ML and F on EFC

The statistically analyzed data of ML and F for EFC (Table 2) shows that both ML and F significantly affect the EFC. The average maturity level ML_3 had significantly higher value of EFC (0.1613) compared to both ML_1 (0.1606 ha h^{-1}) and ML_2 (0.1605 ha h^{-1}). The average EFC on ML shows that field size F_3 had significantly higher EFC (0.1744 ha h^{-1}) and F_1 had significantly lower EFC (0.1435 ha h^{-1}). It could be concluded that if ML is high and F is larger which results higher productive/effective time and lower time lost for unnecessary stops during operation in the field, resulting in greater EFC. Individual analysis under each field and maturity level supported the above findings. The EFC values under fields F_1, F_2 and F_3 at ML_1 were 0.1435, 0.1644 and 0.1741 ha h^{-1}; at ML_2 were 0.1431, 0.1645 and 0.1739 ha h^{-1}; and at ML_3 were 0.1438, 0.1652 and 0.1750 ha h^{-1} respectively.

Effect of S and F on EFC

The statistically analyzed results of effects of machine forward speed (S) and field size (F) on effective field capacity (EFC) have been shown in Table 2. The table depicted that both S and F significantly affected the effective field capacity (EFC). The F_3 had significantly greater value of EFC (0.1744 ha h^{-1}) compared to both at F_2 (0.1646 ha h^{-1}) and F_1 (0.1435 ha h^{-1}) when averaged over all field speeds. The average values of EFC over field size showed that S_1 had significantly greatest EFC (0.1617 ha h^{-1}) and S_2 had significantly lowest EFC (0.1602 ha h^{-1}). Therefore, it could be concluded that higher the forward speeds and larger the field size, more will be the productive/effective time and less will be the time lost during unnecessary stops during field operation, resulting greater EFC. Individual analysis under each field and machine speed supported the above findings. The EFC values under fields F_1, F_2 and F_3 at S_1 were 0.144 ha h^{-1}, 0.167 and 0.174 ha h^{-1}, at S_2 were 0.142 ha h^{-1}, 0.164 ha h^{-1} and 0.174 ha h^{-1} and at S_3 were 0.145 ha h^{-1}, 0.163 ha h^{-1} and 0.174 ha h^{-1} respectively. Generally it could be concluded from the results and discussion that EFC increased by increasing field size and the effect of S within the same field is not ignorable.

Effect of ML and F on FE

The effect of ML and F on FE was statistically analyzed and results show that both ML and F significantly affect FE (Table 3). The average ML_3 had significantly greater value of FE (72.61%) compared to both at ML_1 (72.32%) and ML_2 (72.23%). The average FE values over ML depicts that field size F_3 had significantly higher value of FE (78.44 %) and F_1 had significantly lower FE (64.52%). Therefore, it can be concluded that there is no noticeable change in FE while moving in the same field. The ML has no significant effect on FE while working in the same size field. However, the mutual effect of ML and F results that higher value of ML and F, has higher productive/effective time and lower time lost in unnecessary stops during the field operation resulting higher FE value. Individual analysis under each field and maturity level also supports the above findings. The FE values under maturity levels ML_1, ML_2 and ML_3 at F_1 were 64.53, 64.37 and 64.66%, at F_2 were 74.06, 74.12 and 74.42% and at F_3 were 78.38, 78.22 and 78.75% respectively. It can be concluded that FE increased by increasing field size and the effect of ML within the same field is ignorable.

Effect of S and F on FE

The statistically analyzed results of effects of S and F on FE (Table 3) indicate that both S and F significantly affect the field efficiency. The F_3 had significantly higher value of FE (78.48%) than both at F_2 (74.19%) and F_1 (64.52%). Average FE values over field size show that FE has significantly higher value (87.48%) at S_1 and FE has lowest value (60.91%) at S_2. It can be concluded that smaller the S and larger the field size, greater will be the FE. The FE under fields F_1, F_2 and F_3 at S_1 were 89.29, 90.39 and 94.26%, at S_2 were 60.83, 70.45 and 75.02% and at S_3 are 54.90, 61.77 and 66.05% respectively. FE increases with increase in field size and decreases with increase in S within the same field size.

Effect of ML and F on DE

The statistically analyzed results of effects of crop ML and F on machine digging efficiency (DE) are shown in Table 4. The table indicates that both ML and F significantly affected the DE. The average ML_1 had significantly higher value of DE (90.86%) compared to both ML_2 (89.31%) and ML_3 (87.26%) The average DE values over maturity levels showed that F_1 and F_3 had significantly higher DE (89.38 %) and F_2 had significantly lower DE (89.18%). It can be concluded that decrease in ML and increase in F results higher DE. This is due to the fact that with the increase in ML the attachment of pod and plant become weak and more pods scattered in the soil decreasing DE value. On the other hand, the DE increases by increasing the field size because of the smooth operation of the machine in the large sized field due to less number of turns. The DE under fields F_1, F_2 and F_3 at ML_1 were 91.18, 90.68 and 90.71%, at ML_2 were 89.74, 89.64 and 90.03% and at ML_3 were 87.21, 87.21 and 87.37% respectively. It can be concluded from the results and discussion that DE decreased with increasing ML and the effect of field size is not ignorable.

Effect of S and F on digging efficiency (DE)

Table 4 presents the effect of S and F on digging efficiency (DE). The table depicts that both S and F have significant effect on DE. The F_3 and F_1 had significantly higher values of DE (89.38%) compared with F_2 (88.18%) for all average vales of S. The average values of DE show that S_1 has significantly higher DE (89.41%) and S_3 has significantly lower DE value (89.20%). It can be concluded that lower the S and larger the field size, more will be the DE value. The DE values under fields F_1, F_2 and F_3 at S_1 were 89.31, 89.23 and 88.89%, at S_2 were 89.34, 89.24 and 88.9% and at S_3 were 89.34, 88.94 and 89.2% respectively. It can be concluded that DE increases with increase in field size and decreases with increase in S in the same field. Results also show that there is almost linear increase in DE with increase in field size.

Table 2. Effect of ML and S on EFC with respect to F

ML/S	F_1	F_2	F_3	Mean	LSD (0.05)
ML_1	0.1435^{ab}_{C}	0.1644^{b}_{B}	0.1741^{b}_{A}	0.1606^{b}	0.0005
ML_2	0.1431^{b}_{C}	0.1645^{b}_{B}	0.1739^{b}_{A}	0.1605^{b}	0.0001
ML_3	0.1438^{a}_{C}	0.1652^{a}_{B}	0.1750^{a}_{A}	0.1613^{a}	0.0003
Mean	0.1435_{c}	0.1649_{b}	0.1744_{a}	0.1608	0.0001
LSD (0.05)	0.0004	0.0004	0.0003	0.0003	
S1	0.144^{b}_{C}	0.167^{a}_{B}	0.1743^{b}_{A}	0.1617^{a}	0.0003
S2	0.142^{c}_{C}	0.164^{b}_{b}	0.1748^{a}_{A}	0.1602^{c}	0.0003
S3	0.145^{a}_{C}	0.163^{c}_{B}	0.1741^{b}_{A}	0.1606^{b}	0.0003
Mean	0.1435_{c}	0.1646_{b}	0.1744_{a}	0.1608	0.0001
LSD (0.05)	0.0004	0.0003	0.0003	0.002	

Table 3. Effect of ML and S on FE with respect to F

ML/S	F_1	F_2	F_3	Mean	LSD (0.05)
ML_1	64.53^{b}_{C}	74.06^{b}_{B}	78.36^{b}_{A}	72.32^{b}	0.1320
ML_2	64.37^{c}_{C}	74.12^{b}_{B}	78.22^{b}_{A}	72.23^{b}	0.1155
ML_3	64.66^{a}_{C}	74.42^{a}_{B}	78.75^{a}_{A}	72.61^{a}	0.1240
Mean	65.52_{c}	74.19_{b}	78.44_{a}	72.39	0.0562
LSD (0.05)	0.01303	0.1966	0.1523	0.1257	
S1	89.39^{a}_{AB}	90.38^{a}_{B}	94.26^{a}_{A}	87.48^{a}	0.2207
S2	60.83^{b}_{C}	70.45^{b}_{B}	75.02^{b}_{A}	68.76^{b}	0.1309
S3	54.90^{c}_{C}	61.77^{c}_{B}	66.05^{c}_{A}	60.91^{c}	0.1399
Mean	64.52_{c}	74.19_{b}	78.48_{a}	72.39	0.0652
LSD (0.05)	0.5838	0.8886	0.1523	0.4111	

Table 4. Effect of ML and S on DE with respect to F

ML/ S	F_1	F_2	F_3	Mean	LSD (0.05)
ML_1	91.18^{a}_{A}	90.68^{a}_{B}	90.71^{a}_{B}	90.86^{a}	0.3103
ML_2	89.74^{b}_{B}	89.64^{b}_{C}	90.03^{b}_{A}	89.31^{b}	$6.9*10^{-17}$
ML_3	87.21^{C}_{B}	87.21^{c}_{B}	87.37^{c}_{A}	87.26^{c}	$1*10^{-15}$
Mean	89.38_{a}	89.18_{b}	89.37_{a}	89.31	0.0812
LSD (0.05)	0.1454	0.6900	0.2183	0.0392	
S_1	89.31^{a}_{C}	89.34^{a}_{B}	89.5^{a}_{A}	89.41^{a}	0.1141
S_2	89.23^{a}_{A}	89.24^{b}_{C}	89.37^{b}_{B}	89.31^{b}	$96*10^{-17}$
S_3	88.89^{a}_{A}	88.99^{c}_{B}	89.3^{b}_{A}	89.2^{c}	0.1013
Mean	89.38_{a}	88.18_{b}	89.37_{a}	89.31	0.0812
LSD (0.05)	0.114	0.4300	0.1713	0.0639	

Effect of ML on crop yield

The effect of maturity level on crop yield is shown in Figure 7. The figure depicted that the crop yield increases with increase in maturity level. It is due to prolonged period of pods in the soil resulting matured growth and gain in more mass, which ultimately improved crop yield. It could be concluded from the results and discussions that the maturity level significantly affected the crop yield.

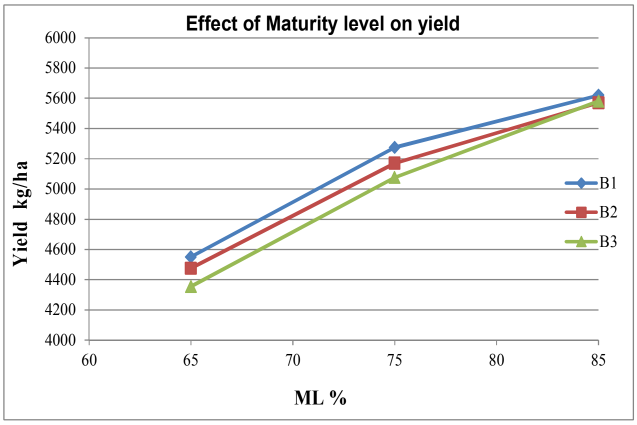

Fig. 7. Effect of maturity level on crop yield

Effect of ML on crop yield and recoverable loss

The effect of ML on crop yield and recoverable losses is shown in Figure 8. The figure shows that both crop yield and recoverable losses increases by increasing maturity level of the crop. The increase in the recoverable losses above 75% increased significantly than the increase in crop yield.

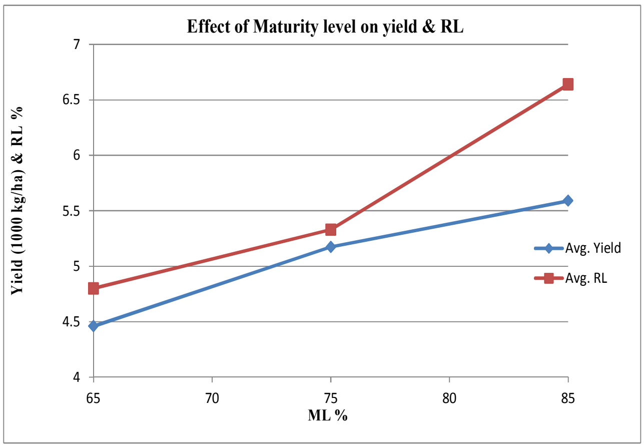

Fig. 8. Effect of maturity level on crop yield and recoverable loss

Effect of maturity level on crop yield and irrecoverable loss

The effect of ML on crop yield and IRL is shown in Figure 9. The figure shows that both crop yield and irrecoverable losses increases by increasing the maturity level of the crop. The increase in the irrecoverable losses above 75% increased significantly than the increase in crop yield. From the above analysis, it can be concluded that the best ML for harvesting was taken to be 75%.

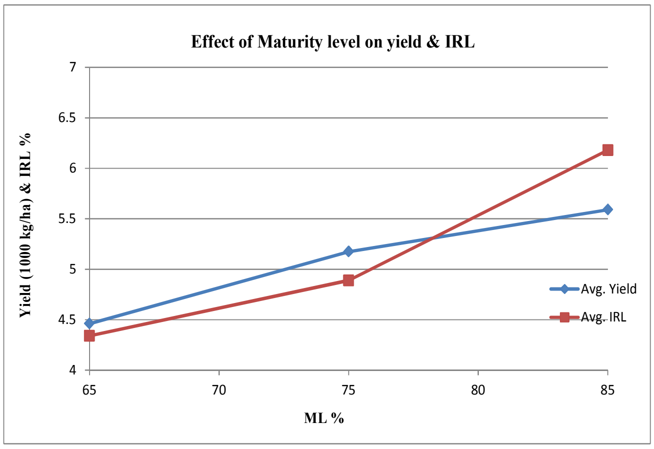

Fig. 9. Effect of maturity level on crop yield and irrecoverable loss

Conclusions

The average yield of groundnut in Pakistan is nearly 0.88 tons/ha. Groundnut is an important rotational cash crop. The existing digger/shaker was tested at Agricultural Mechanization Research Institute (AMRI) Wing, Jhang Road, Faisalabad. During field testing, the machine performance was found unsatisfactory. Keeping in view, the existing problems, the necessary modifications were incorporated to improve the field efficiency of the digger. During modification, the space between the supporting bars and conveyors was optimized, blade was divided into three continuous welded pieces, front roller was removed and small pegs were welded on the front conveyor to overcome these problems. Finally, the field test was conducted at the farms of Barani Agricultural Research Institute (BARI), Chakwal for performance evaluation of machine. Field performance of the digger was evaluated at three maturity levels of the crop, three plot sizes at three different forward speeds of machine. Data regarding productive weights, seenable and unseenable weights were collected and statistically analyzed. Results showed that maximum digging efficiency was 89.31% at 75% maturity level and the field efficiency was found to be 89.31% at 1.85 km h^{-1}. The recoverable and irrecoverable losses at 1.85 km h^{-1} were 5.14 and 5.55% respectively. The improved design of the groundnut digger resulted a better fuel economy in comparison of the existing digger.

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