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Evaluation of different weeding methods for groundnut in northern Iran

Saeed Firouzi1* and Mohammadreza Alizadeh2

1Department of Agronomy, Rasht Branch, Islamic Azad University, Rasht, Iran.
2Agricultural Engineering Department, Rice Research Institute of Iran, Rasht, Iran.

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This study was carried out to investigate the energy consumption, work capacity, and operation cost of four weeding methods of groundnut (Arachis hypogaea) in northern Iran. The weeding methods included two power tiller operated weeder (weeding using power tiller operated cultivator and rotavator at three forward speeds of 1, 1.5 and 2 km h⁻¹), manual weeding by wheel cultivator, and traditional weeding method (hand weeding by trench hoe). The experiment was planed based on randomized complete block design (RCBD) with eight treatments and three replications. The results revealed that the highest work capacities at the first and second weeding stages averaged by 8.10 and 7.80 h ha⁻¹, respectively, and were observed at weeding by power tiller operated rotavator at forward speed of 2 km h⁻¹. The lowest energy consumption (307.8 MJ h⁻¹) was obtained in weeding by manual cultivator. The results also indicated that power tiller operated rotavator at the forward speeds of 1, 1.5 and 2 km h⁻¹ had the highest benefit/cost ratio of 2.06, 2.03 and 1.96, respectively. Thus the power tiller operated rotavator at forward speed of 1 km h⁻¹ was the most suitable method of groundnut weeding.

Key words: Groundnut, weeding cost, energy consumption, work capacity.

INTRODUCTION

Groundnut is the fourth oil seed crop mostly produced in the world after soybean, rapeseed and cotton seed and its seed contains 22 to 26% protein and 45 to 50% oil. This is a food with high nutrition value for humans, especially for those suffering from malnutrition in rural areas (FAS, 2010; FAO, 1998). About 3500 ha of cultivated area in northern Iran is covered by groundnut crop and the annual production of pod equals to 12250 ton (Kheyri, 2007). Regarding the problem of inadequacy of raw oil as an initial material for food oil in Iran, thus the study on the different aspects of groundnut production is highly important.

Weed population in the groundnut fields is an important factor which affects product yields. Therefore, in order to improve production yield, weed control is a necessity. The most common methods of weed control are mechanical, chemical, biological and cultural methods. Out of these four methods, mechanical weeding either by hand tools or weeder are most effective in both dry and wet lands (Nag and Dutt, 1979; Gite and Yadav, 1985; Gite and Yadav, 1990). Mechanical weeding is more likely to be sustainable than chemical weeding, because it carries fewer risks (financial, health and environmental) and easier to maintain with existing skills and facilities (Stevens, 2000). It not only destroys weeds but also makes the soil soft for better aeration and water penetration (Biswas et al., 1990). Mechanical weeder range from basic hand tools to sophisticated tractor driven or self-propelled machines. Such weeder include cultivation tools such as hoes, harrows, tined implements, brush weeder, cutting tools like mowers and trimmers, as well as implements like thistle-bars (Bond and Turner, 2005). Manual weeding by trench hoe has a good quality but it is a time consuming method. Also weed type and density, the time of weeding operation and soil moisture content intensify the operation difficulty. Geel et al. (2008) reported that field capacity of manual weeding by trench hoe increased up to 0.017 ha h⁻¹ due to an increase in soil moisture content and weeding index at the soil...
moisture content of 13.52% achieved 98.92%. Based on this, the field capacity of manual cultivators was reported to be 0.001 to 0.04 ha h\(^{-1}\) depending on the soil moisture content. They also reported that the amount of consumed energy was varied from 8.34-40.05 kJ min\(^{-1}\) depending on the soil moisture content. In addition, the field capacity of a wheel manual cultivator after ergonomic modification and its weeding index was found to be 0.048 ha ha\(^{-1}\) and 92.5%, respectively (Yadav and Pund, 2007). In another study in Sudan, weeding efficiency of a manual wheel cultivator for beans inter row weeding was equalled to 70.6%. In this study, there was no significant difference between crop yields in hand weeding and weeding by manual cultivator (Elhassan, 2008). In addition, some studies were conducted on weeding by rotary motorized weeder. In this regard, field capacity of a rotary power weeding machine and its weeding index were reported to be 0.053 ha ha\(^{-1}\) and 95%, respectively. Furthermore, fuel consumption of the machine averaged 0.7 L h\(^{-1}\) (Manuwa et al., 2009). Alizadeh (2011) studied the field performance of hand driven and power weeder in the paddy field as compared to manual weeding. The results indicated that the power weeder showed better field performance compared to the other treatments. Some investigations were made on the effect of tractor drawn weeder on the dry matter of weed and crop (Pullen and Cowell, 1997; Welsh et al., 1997; Reddiex et al., 2001). A review on the weeding operation of groundnut in Iran indicates that the groundnut fields in northern Iran are often small and the number of agricultural tractors is very limited. Therefore, the use of sophisticated tractor mounted implements like in Spain and U.S. groundnut farms is not economically. On the other hand, manual weeding by trench hoe is very costly and time consuming. In addition, simultaneity of growth duration of groundnut with rice cultivation has resulted in the lack of labour accessibility in this region. Therefore, in order to protect, to enhance product yield and to decrease its costs, there must be some methods, which remove the mentioned problems as well as lack of labourer. Regarding significant distribution of power tiller in Guilan province and its suitability with the size of groundnut fields, this study was done to investigate the field performance of four small scale weeding methods including weeding by power tiller operated cultivator, power tiller operated rotavator in combination with weeding by manual wheel cultivator and traditional weeding (using trench hoe as the common weeding method in the region).

**MATERIALS AND METHODS**

This study was carried out in a groundnut farm of Kiasahr city, Guilan province, North of Iran (37°25' 15"N, 49° 56'56"E and 16.2 m below the sea level). Experimental treatments were manual weeding with trench hoe (TH), weeding by manual wheel cultivator (MWC), weeding by power tiller operated cultivator at three forward speeds of 1, 1.5 and 2 km h\(^{-1}\) (TLC1, TLC1.5, TLC2, respectively), and weeding by the use of power tiller operated rotavator at three forward speeds of 1, 1.5 and 2 km h\(^{-1}\) (TLR1, TLR1.5, TLR2, respectively). The experiment was planed based on randomized complete block design (RCBD) with eight treatments and three replications. Each experimental plot was 40 × 5 m\(^2\). In order to row planting of groundnut, after land preparation, the furrows were provided using a tiller furrower. The soil type of experimental farm was sandy loam and its moisture contents at first and second weeding stages were 10.7 and 8.8% w.b., respectively. *Paspalum distichum* was dominant weed in the experimental farm.

Regarding the least distance between tiller’s wheels as the mean of driving force for six of 8 treatments, the inter-row and intra-row spacing were set on 70 and 30 cm, respectively. A common groundnut seeds in Guilan province, namely NC2 variety was chosen in the experiment. The planted seeds were covered with soil using a pair of shovel blades mounted on the rear drawbar of power tiller.

For each treatment, work capacity, energy inputs, cost of operation, crop yield, and benefit/cost ratio were measured.

The work capacity or time required for weeding per hectare in different weeding operations was calculated by the following equation (Konaka, 2005):

\[
W_c = \frac{1}{C_e}
\]

Where, \(C_e\) is the effective field capacity (ha h\(^{-1}\)) and \(W_c\) is work capacity of the weeder (ha\(^{-1}\)).

The energy requirements associated with each mechanical weeding operation were computed by summing up the following unit requirements:

1. The energy contained in the machines and equipment (energy/time × time/area).
2. The fuel used (volume/time × time/area × energy/volume).
3. The energy input of the operators (energy/time × time/area).

Machinery mass unit energy was considered 109 MJ kg\(^{-1}\) (Pimentel, 1992). Weights of MWC, TLC, TLR and power tiller were recorded at 9.6, 19, 63 and 281 kg, respectively. Therefore, total machines' energy was simply calculated by measuring their useful working hours.

Labour unit energy also was considered 1.96 MJ h\(^{-1}\). Therefore, total labour energy for each weeding operation was calculated by multiplying working hours in labour unit energy and then dividing by the area covered in a working day.

In order to measure fuel consumption of the power tiller operated weeder, at the beginning and the end of each trial, fuel tank was filled by diesel fuel. The amount of added fuel at the end of experiment was considered as fuel consumption in weeding operation (RNAM, 1995). Specific energy for diesel fuel was considered 47.8 MJ L\(^{-1}\). Thus, the total energy of consumed fuel was determined through fuel amount multiplied by its specific energy (Safa and Tabatabaeefar, 2002).

It should be mentioned that daily working hour in the region was usually nine hours a day. At the time of harvest, crop yield of each experimental plot was recorded after manual pod picking. Then crop yield per surface unit area (ha) for each treatment was calculated.

Benefit-cost ratio (B/C) was calculated by dividing the gross product value into the total production cost in order to determine economic efficiency (Dagistan et al., 2009). Analysis of variance (ANOVA) of the variables and means comparison (LSD) of the treatments was performed by MSTATC statistical software.
Table 1. Results of analysis of variance (ANOVA) for dependent variables.

<table>
<thead>
<tr>
<th>Source of variations</th>
<th>Degree of freedom</th>
<th>Work capacity</th>
<th>Energy consumption</th>
<th>Crop yield</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Stage 1</td>
<td>Stage 2</td>
<td></td>
</tr>
<tr>
<td>Replication</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Method of weeding</td>
<td>7</td>
<td>7657.753**</td>
<td>2487.63**</td>
<td>458098.6**</td>
</tr>
<tr>
<td>Error</td>
<td>14</td>
<td>48.613</td>
<td>17.55</td>
<td>9028.16</td>
</tr>
<tr>
<td>c.v.</td>
<td></td>
<td>18.84%</td>
<td>15.69%</td>
<td>10.60%</td>
</tr>
</tbody>
</table>

** significant at α = 1%.

Table 2. Comparison of variable means studied for different methods of groundnut weeding.

<table>
<thead>
<tr>
<th>Method of weeding</th>
<th>Work capacity (h ha⁻¹)</th>
<th>Energy consumption (MJ ha⁻¹)</th>
<th>Operation cost (USD ha⁻¹)</th>
<th>Crop yield (kg ha⁻¹)</th>
<th>Benefit-cost ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>TH</td>
<td>151.3 a</td>
<td>439.5 c</td>
<td>474.53</td>
<td>4031 a</td>
<td>1.76</td>
</tr>
<tr>
<td>MWC</td>
<td>70.07 b</td>
<td>1257 db</td>
<td>218.36</td>
<td>3175 ab</td>
<td>1.48</td>
</tr>
<tr>
<td>TLC 1</td>
<td>18.30 c</td>
<td>986.1 c</td>
<td>180.27</td>
<td>2981 c</td>
<td>1.38</td>
</tr>
<tr>
<td>TLC 2</td>
<td>8.90 c</td>
<td>727.7 d</td>
<td>140.44</td>
<td>3237 de</td>
<td>1.64</td>
</tr>
<tr>
<td>TLR 1</td>
<td>11.70 c</td>
<td>1446 a</td>
<td>235.65</td>
<td>3947 a</td>
<td>2.06</td>
</tr>
<tr>
<td>TLR 1.5</td>
<td>10.70 c</td>
<td>1108 bc</td>
<td>157.75</td>
<td>3754 ab</td>
<td>2.03</td>
</tr>
<tr>
<td>TLR 2</td>
<td>8.10 c</td>
<td>901 d</td>
<td>116.21</td>
<td>3581 bc</td>
<td>1.96</td>
</tr>
</tbody>
</table>

*There is no significant difference between treatments with similar letters in each column (LSD 1%). TH: manual weeding with trench hoe; MWC: Weeding by manual wheel cultivator, TLC1, TLC1.5, and TLC2 are weeding by power tiller operated cultivator with three forward speeds of 1, 1.5 and 2 km h⁻¹, respectively; TLR1, TLR1.5, and TLR2: weeding by the use of power tiller operated rotavator a three forward speeds of 1, 1.5 and 2 km h⁻¹, respectively.

RESULTS AND DISCUSSION

Results obtained by analysis of variance (Table 1) showed that the effects of weeding method on work capacity, energy consumption, and crop yield were significant (p< 0.01).

Work capacity

As shown in Table 2, the highest work capacity (time required for weeding per hectare) belonged to the hand weeding by TH (151.3 and 86.1 h ha⁻¹) at the first and the second stages, respectively. There were significant differences in work capacity of weeding by trench hoe and weeding by manual cultivator (MWC) at the first and second stages. The work capacity of weeding by MWC was less than half of that of hand weeding by trench hoe at the first stage (70.07 compared to 151.3 h ha⁻¹). This shows how much a simple machine can affect the speed of weeding operation. In another study, the work capacity of weeding by TH was decreased from 1000 to 58.82 h ha⁻¹ (field capacity 0.001-0.017 ha h⁻¹) depend as soil moisture content increased from 8 to 13.5% on wet basis (Goel et al., 2008). Some of the differences between their results with the results of this study may be contributed to the weed type, soil moisture content at the time of weeding and soil texture. Their study also showed that the work capacity of weeding operation by three kinds of MWC varied from 1000 to 25 h ha⁻¹ (field capacity 0.001 to 0.04 ha h⁻¹) with increase in soil moisture content from 8 to 13.5% w.b. In addition, the highest work capacity was reported to be 11.63% w.b. which was more than the soil moisture content at the first and second stages of the present study (10.7 and 8.8%, respectively). In addition, the work capacity of a modified manual wheeled cultivator was found to be 20.83 h ha⁻¹ (Yadav and Pund, 2007) which is less than that of this research. Furthermore, investigation on the work capacity at the other studied treatments showed that there were no significant differences among the work capacities of power tiller operated treatments. However, the least work capacity was obtained for power tiller operated rotavator at forward speed of 2 km h⁻¹ (8.1 and 7.80 h ha⁻¹ for the first and second stages, respectively). The work capacities of TLC (8.90 and 8.43 h ha⁻¹) for the first and second stages, respectively) were slightly less than those of TLR. This might be due to high weed population in the experimental plot and their inhibition of continuous moving of TLC. It is evident that the time needed for cleaning weeds wrapped to the cultivator blades increases the work capacity. However, power tiller rotavator readily cut, chop
and bury the weeds by active rotation of its J-shaped blades. The results also showed that work capacity in weeding by TH at the first stage was less than that of the second stage (Table 2). This may be attributed to further growth of crop at the latter stage and consequently limitation of weeds growth on rows.

**Crop yield**

According to the Table 2, although there was no significant difference between crop yield in hand weeding by TH and weeding by power tiller operated rotavator at forward speeds of 1 and 1.5 km h\(^{-1}\), however the maximum crop yield (4031 kg ha\(^{-1}\)) was measured in the treatments of TH. This could be attributed to more clean weeding by trench hoe. Similar result was reported by Biswas et al. (1990). Among the treatments with rotavator, the maximum crop yield (3947 kg ha\(^{-1}\)) was belonged to the forward speed of 1 km h\(^{-1}\). Since, power tiller operated rotavator is an engine operated tool thus with an increase of forward speed by changing the gears, the cutting intervals of blades on the ground decreases. This could be resulted in less soil manipulation by power-driven rotavator. Thus, the maximum soil manipulation was achieved at the lowest forward speed of 1 km h\(^{-1}\) which leads to higher crop yield.

**Energy consumption**

It can be seen from Table 2 that the lowest value of energy consumption of 307 MJ ha\(^{-1}\) was belonged to weeding by MWC, followed by hand weeding by TH (439.5 MJ ha\(^{-1}\)). The highest energy consumption (1446 MJ ha\(^{-1}\)) was registered in weeding by TLR with forward speed of 1 km h\(^{-1}\). This may be due to the high unit energy of fuel in power tiller operated methods compared to manual weeding (Safa and Tabatabaeefar, 2002). Consequently, this energy in combination with energy consumed for manufacturing machines, resulted in increase in energy consumption, leading to high working capacities. Significant difference in energy consumption at different forward speeds for power tiller treatments is contributed to their different work capacity. Results of the study of Umar (2003) showed that the energy consumption for manual weeding of groundnut in semi-arid regions of Nigeria varied from 227.5 to 680.2 MJ ha\(^{-1}\) (mean value of 452.35 MJ ha\(^{-1}\)) which is close to the energy input in hand weeding in this research (439.5 MJ ha\(^{-1}\)). Their study also showed that the energy consumption for manual cum mechanical weeding of groundnut varied from 522.4 to 1735 MJ ha\(^{-1}\) (Umar, 2003). In addition, research of Laguë and Khelifi (2001) illustrated that the total energy requirements were the lowest (370 MJ ha\(^{-1}\)) for the strategies that required one pass of the rotary hoe and one pass of the mechanical cultivator in corn weeding. This amount is about half of the lowest input energy in motorized weeder in this research (727.7 MJ ha\(^{-1}\) for power tiller operated cultivator). This difference shows the higher energy efficiencies of tractor operated weeder compared to the power tiller operated implements. The least mean value of the energy input to produce a unit quantity of the groundnut was determined 0.0899 MJ kg\(^{-1}\) ha\(^{-1}\) in case of weeding with manual wheeled cultivator and the most value (0.3959 MJ kg\(^{-1}\) ha\(^{-1}\)) was obtained in weeding with power tiller operated cultivator at forward speed of 1 km h\(^{-1}\). In another research, groundnut yield in semi-arid region of Nigeria was achieved 598 to 655 kg ha\(^{-1}\) for manual and manual cum mechanical crop production. The mean values of energy input for two categories of manual and manual cum mechanical weeding of groundnut were determined 0.95 MJ kg\(^{-1}\) ha\(^{-1}\) (468.92 MJ/598 kg) and 1.79 MJ kg\(^{-1}\) ha\(^{-1}\) (1173.68 MJ/655 kg), respectively (Umar, 2003). The higher amounts of unit energy for weeding of groundnut in research of Umar (2003) can be related to the less crop yield in his study.

**Cost of operation**

Results showed that the maximum operation cost of 475 USD ha\(^{-1}\) was related to the hand weeding by TH. In addition, the cost of weeding by MWC was calculated about 262 USD ha\(^{-1}\) (Table 2).

The results of Goel et al. (2008) indicated that the operation costs in weeding by TH and a modified MWC were estimated to 2450 and 244 Rupees per hectare, respectively. Thus the weeding cost in hand weeding by TH was about 10 percent of that of weeding by MWC.

The results also showed that the operation costs in treatments with power tiller operated rotavator were lower than that of the hand weeding methods (Table 2). Furthermore, the weeding cost decreased as forward speed increased. Finally, the treatment of power tiller operated rotavator with forward speed of 2 km h\(^{-1}\) had the minimum operation cost (116 USD ha\(^{-1}\)) which was about 25% of weeding cost by TH (475 USD ha\(^{-1}\)).

According to the Table 2, the benefit-cost ratio in weeding by power tiller operated rotavator at forward speeds of 1, 1.5 and 2 km h\(^{-1}\) were 2.06, 2.03 and 1.96, respectively, that are more than that of the other treatments.

**Conclusions**

The following conclusions were drawn from the results of this research:

- The least time requirement or work capacity (7.80 h ha\(^{-1}\)) was obtained in weeding by power tiller operated rotavator at forward speed of 2 km h\(^{-1}\).
- The lowest value of energy consumption of 307 MJ ha\(^{-1}\)
belonged to weeding by manual wheeled cultivator. The maximum crop yield (4031 kg ha\(^{-1}\)) was measured in weeding with trench hoe. There was no significant difference between crop yield in hand weeding by trench hoe and weeding by power tiller operated rotavator at forward speeds of 1 and 1.5 km h\(^{-1}\). The maximum operation cost of 475 USD ha\(^{-1}\) was registered in hand weeding by trench hoe. The highest benefit-cost ratios were contributed to the treatments of power tiller operated rotavator with the best index of 2.06 at forward speed of 1 km h\(^{-1}\). Therefore, considering to importance of the economical aspect, this treatment was the appropriate method of groundnut weeding.

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