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# Study of Tillage Systems Effect and Number of Weeding on Species of Weeds and Yield of Corn

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**Abstract**

Constraints to effective weed management may be the main reason for the small area under minimum tillage (MT) in smallholder farming in Iran. The effect of tillage systems and intensity of hand hoe weeding on the growth of weeds and maize (SKC 108) was investigated in the 2013–2014 growing season a field experiment at Tehran Research Station (28830.920E, 20823.320S). The experiment was a split-plot randomized complete block design with four replications. Tillage was the main plot factor (conventional tillage – mouldboard tillage (MBT) compared against minimum tillage (MT) – disc) and hoe weeding rate the sub-plot factor. Hoe weeding was done either two times (high weeding intensity), one (low weeding intensity) and no weeding during the cropping season. There was markedly greater early season weed growth in minimum tillage (MT) relative to mouldboard tillage (MBT) in crop season. MT tillage system had higher weed biomass (285.26 g/m$^2$) measured than MBT (278.63 g/m$^2$) system. The high weeding intensity treatment had lower weed growth and better maize yield than high weeding intensity. MBT had the higher maize ear length, 1000 grain weight, maize total dry weight, harvest index, total maize N uptake, grain N uptake and grain N concentration which translated significantly higher than in MT system. Maize grain yield obtained from MT system was less than (4.250 t/ha$^1$) compared to (4.931 t/ha$^1$) in MBT. Results suggest that MT systems require early and frequent hoe weeding even many years to reduce weed infestations and improve crop growth. This higher demand on a smallholder household's limited labor supply throughout the cropping season will be a key determinant of the spread and adoption of MT systems in Iran.

**Keywords**: Minimum tillage, mouldboard tillage, ear length, total N uptake, grain N concentration.

## 1. Introduction

In Iran, the conservation agriculture package being promoted comprises the simultaneous application of continuous minimum tillage, a target of at least 30% permanent soil cover. Although the majority of smallholder farmers in the region are at most practicing some aspects of improved minimum tillage only, yield increases of between 30 and 120% have been reported on farmers' fields in Zambia and Zimbabwe [10, 17 and 20]. The increase in yield is attributed mainly to better crop management through early planting; fertilizer application and improved timeliness of field operations, particularly weed management. the majority of smallholder farmers' fields are still under conventional plough tillage. The area under minimum tillage rarely exceeds 1 ha per farming household [1, 17]. In smallholder agriculture in Iran, the principal factor limiting the area of cropped fields is the number of necessary weedings following planting. In southern Africa there have been reports of a doubling in labor required for hand hoe weeding of maize under MT tillage as well as increases in weeding intensity in minimum tillage compared to conventional mouldboard plough tillage [1, 10, and 17]. Research done in the region indicated that minimum tillage was associated with high weed density scores and increased weed biomass [19, 24]. Giller et al. [7] noted that in most developed

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countries, the benefits of conservation agriculture are underpinned by a higher dependence on herbicides to enable farmers to effectively cope with increased weed emergence and growth under conservation agriculture. In fact, significant adoption of conservation agriculture by smallholder farmers in Brazil only occurred when herbicides such as glyphosate *(N-phosphono-methyl glycine)* became available and affordable [3]. Gowing and Palmer [9] reported that many of these Brazilian farmers often resort to tillage when their access to herbicides for weed control is limited. However, herbicide use in smallholder agriculture in Iran is low due to the relatively high costs and limited availability. As a result, the majority of smallholder farmers use hand hoes to weed; a method that is tedious with many smallholder households investing 50-70% of their total available labor to weeding [4]. Despite this considerable investment in labor, crop yields remain low due to a combination of late planting, delayed weed control and poor soil fertilization [22]. Throughout Iran, smallholder farmers have very limited farm power resources (animal and human) and this leads to serious labor bottlenecks at the beginning of the cropping season. Early in the season weeding competes with other operations like planting and livestock herding which results in weeding often being postponed to a later date when the crop has already suffered significant yield loss [6, 25]. In addition, all other field operations such as nitrogen fertilization are also delayed, further reducing crop yield. Thus, the issue of effective weed management under these systems has most likely limited their adoption by resource-poor farmers. The objective of the present study was to determine the effect of tillage systems and intensity of hand hoe weeding on weed, maize growth. The maize crop was grown under mouldboard and minimum tillage systems in two years. The two tillage systems were representative of current conventional and minimum tillage (MT) systems being practiced in Iran.

## 2. Materials and Methods

### *2.1.Location*

Field experiment was conducted in 2013–2014 growing season at the Velenjak Valley (35°47'45.8"N, 51°23'58.3"E; 1700 m above sea level) in Tehran, Iran. The climate is semi-arid with mean annual maximum and minimum daily air temperatures of 34.9 and 7.5 ˚C, respectively, yearly average precipitation of 429 mm. The soil was analyzed for pH (extract 1:2.5 in water), C (Walkley-Black) and N concentration (Kjeldahl), $CaCO_3$ (potentiometry) and water content at field capacity and wilting point (Richard pressure plates) (Table 1). The field was fallow during year previous to the start of the experiment.

**Table 1**. Physical and chemical soil analysis of the field

| Texture | Sand | Silt (%) | Clay | K (ppm) | P (ppm) | N (%) | O.C (%) | pH | Ec (ds/m) | Depth (cm) |
|---|---|---|---|---|---|---|---|---|---|---|
| Si-L | 30.8 | 53.75 | 15.5 | 202.5 | 11.83 | 0.06 | 0.44 | 7.9 | 0.64 | 0-20 |
| Si-L | 34.8 | 50.75 | 14.5 | 152.5 | 8.3 | 0.05 | 0.33 | 7.8 | 0.49 | 20-40 |

### *2.2. Treatments and experimental layout*

The experiment was set up as a split-plot with plots arranged in a randomized complete block design with four replications. Tillage system was the main plot (60 m **x** 6 m) factor and hand hoe weeding intensity was as a sub-plot at two levels (high and low weeding intensity). Weeding at the high intensity treatment were carried out 4 and 7 weeks after planting maize (WAP). The high weeding intensity treatment followed the MT recommendation of frequent weeding aimed at minimizing weed seed return to the soil seed bank. This weeding regime's objective was to provide a clean seedbed for the crop, remove the first weed flush to emerge with the crop, reduce weed competition during the critical first 30 days of crops' growth and remove last weed cohorts emerging at end of the rains. The low weeding intensity treatment comprised hoe weeding a 4 weeks after planting (WAP).

### *2.3. Crop management*

### *2.3. Land preparation*

The two tillage treatments were MBT (conventional tillage – mouldboard tillage) and MT (minimum tillage – disc). Conventional tillage consisted of spring mouldboard ploughing to a depth of 20-25 cm and minimum tillage was tilled with a disk harrow (10-15 cm depth). In the spring, Conventional tillage was done using a donkey-drawn ZimPlow® VS200 mouldboard plough and a depth of 20-25 cm was achieved. Disking was conducted with a 4.6 m wide Sunflower 3300 (Sunflower Mfg., Beloit, KS, USA) disk to an approximate depth of 10-15 cm. Then planting furrows were opened at the recommended spacing for maize of 75 cm and the field was prepared for sowing maize seed. An early maturing maize variety (SKC 108) were planted on 18 May 2014. In both MT and MBT, maize seed was dribbled along planting furrows and thinned at 1 WAP to an intra-row spacing of 0.25 m to give a density of 53000 plants $ha^{-1}$. The balance of nitrogen (200 kg $ha^{-1}$) was applied 40 days after the emergencing of the maize. The weekly irrigation requirements were calculated from the daily ETo (estimated with the Penman–Monteith equation) and the crop coefficients, according to the FAO procedures (Allen et al., 1998). manure was banded along the furrows. The maize crop was harvested in September 2014. Ammonium nitrate (34.5% N) was applied to maize at a rate of 20 kg N $ha^{-1}$ as topdressing at 5 WAP.

### *2.4. Data collection*

#### *2.4.1. Weed biomass and density*

The density and weed biomass were harvested twice; The first sample was performed three weeks after corn germination to determine the weed density and biomass production. The second sample was conducted in six weeks after corn germination. Weed density and biomass per sub-plot were determined from two randomly placed 1 $m^2$ quadrats. Weed density data was collected before weeding at 4 and 7 weeks WAP. Weeds sampled in each sub-plot were cut at ground level and oven-dried at 60 °C to constant weight and the dry weight determined.

#### *2.4.2. Crop yield*

Grain yield and total dry weight (above-ground biomass minus grain) dry matter were determined from a net plot of four central rows each 6 m long in maize. Grain yield was standardized to 14% moisture content. Maize plant to evaluate N test were collected at harvest time from 15 plants. Total plant oven dried at 65 ◦C and ground. A subsample of 2 g was extracted with 50 mL of KCl 2N, shaken for 30 min, filtered through a cellulose filter (Whatman no. 1) and analyzed with a continuous flow analyzer by spectrophotometry UV–Vis (THERMO-OPTEK, Iris Advantage Ers Duo, Thermo Fisher Scientific, Massachusetts, USA). Grain was dried at 65 °C, weighed and ground prior to analyses of total N.

### *2.5. Soil analysis*

Soil was sampled each year before tillage and after maize harvest. Two soil cores from each experimental plot were taken with a 5 cm diameter hand auger (Eijkelkamp Agrisearch Equipment BV, The Netherlands) and the two samples were combined per depth in 0.3 m increments to 1.2 m depth. The soil was fresh-sieved to pass a 2 mm sieve, and 10 g were extracted with 30 mL of KCl 2N solution for determination of $NO3^{-}$–N and $NH4^{+}$–N concentrations colorimetrically with a continuous flow analyzer (AA3, Bran + Luebbe, Norderstedt, Germany).

An N budget was calculated for the maize crop period considering the 0–1.2 m soil layer. Inputs considered were soil mineral N before tillage ($N_{inorg}$ I) and N applied as fertilizer (NF). Outputs included were soil mineral N at maize harvest ($N_{inorg}$ H) and maize N uptake ($N_{uptake}$). Soil mineral N is the sum of $NO3^{-}$–N and $NH4^{+}$–N. The unbalance term (ΔN) of Eq. (1) would include N mineralization – N losses by drainage leaching and by volatilization and denitrification. N mineralization includes soil and maize dry weight biomass net mineralization.

$$\Delta N = N_{inorg}\, H + N_{uptake} - N_{inorg}\, I - NF$$

### *2.6. Statistical analysis*

Multiple comparisons among treatments were performed using least significant difference Duncan test at P = 0.01. Values of soil $N_{inorg}$ and maize $NO3^{-}$–N were transformed prior to analyses by the function y = log(x) to obtain homogeneity of variance. Multiple comparisons among treatments for total soil $N_{inorg}$ in the soil profile (0 – .4 m) were performed using least significant difference Duncan test at P = 0.01.

Prior to analysis, weed density and biomass data were square root transformed (x + 0.5) to homogenize variances [8]. All weed and crop data were subjected to analysis of variance using GenStat Release 9.1 (Lawes Agricultural Trust, 2006) [5]. The means of the treatments were separated by least significant difference (LSD) at 5% level of significance.

## 3. Results and discussion

### 3.1. Seasonal rainfall

The 2013 – 2014 season was characterized by good early rainfall. The rains peaked in November but declined from January to September 2013 (Table 2).

**Table 2**. Monthly air temperature and precipitation during growing period of the maize in 2013 and 2014.

| | 2013 | | | 2014 | | |
|---|---|---|---|---|---|---|
| Month | Air temperature (°C) | Relative Humidity (%) | Precipitation (mm) | Air temperature (°C) | Relative Humidity (%) | Precipitation (mm) |
| January | 4.1 | 72 | 41.3 | 5.1 | 56 | 3.7 |
| February | 3.4 | 62.3 | 36.7 | 6.1 | 54 | 15.3 |
| March | 9.5 | 52.3 | 16.5 | 9.7 | 45 | 31.3 |
| April | 15.6 | 51 | 31.2 | 14.5 | 51 | 74.7 |
| May | 18.6 | 45.3 | 40 | 18.6 | 49.7 | 30.4 |
| June | 22.9 | 37.3 | 9 | 23.1 | 39.7 | 2.2 |
| July | 26.1 | 38.3 | 0 | 27.7 | 35.7 | 0 |
| August | 26.2 | 37.7 | 0 | 28.4 | 32 | 0 |
| September | 20.7 | 40 | 0.4 | 22.8 | 35.7 | 2.5 |
| October | 15.8 | 56 | 10.2 | 15.6 | 48 | 7.1 |
| November | 10.3 | 65.7 | 144.6 | 11.5 | 35 | 0 |
| December | 2.7 | 66.7 | 9 | 2.6 | 66.7 | 14.3 |
| Yearly | 14.7 | 52.1 | 338.9 | 15.5 | 45.7 | 181.5 |

## 3.2. Weed density and biomass

### *3.2.1. Effects of tillage*

Tillage had a significant ($P < 0.001$) effect on weed density (Table 3,4). Weed emergence under MT system was higher than under MBT because without soil inversion weed seeds remained in the soil surface layer where suitable environmental conditions stimulated weed germination. The surface soil layer is characterized by high light penetration, high levels of $O_2$ gas, thermal fluctuations and moisture oscillations which often trigger seed germination [2]. In contrast, under MBT most weed seeds were buried at soil depths where conditions induced seed dormancy leading to low weed emergence. Similar results were obtained in Ghana in which demonstrated that a heavier and earlier weeding burden resulted in MT than in conventional MBT systems [12, 15]. This may necessitate earlier weeding in MT tillage systems than would be the case in MBT, at a time when labor demand is still high. The low weed infestation observed in MBT plots at 28 days after ploughing in this study (Low weeding) is in agreement with the findings of Mabasa et al. [13] from on-farm studies in that showed that spring ploughing reduced the need for subsequent weeding for up to four weeks. MT system was found to has greater weed biomass than MBT in (not significantly) (Table 3, 4). Also, this effect was confounded within the tillage **x** weeding intensity interaction which showed that MT system had 21% more weed biomass than MBT only in the low weeding intensity treatment. As a result, total weed biomass of MT system was higher than that of MBT (not significantly) (Table 4). Since weed density measured after planting did not significantly vary with tillage systems, the differences observed in weed biomass must have been mainly due to variation in weed growth between tillage systems.

Weeds such as *Sorghum halepense* L., *Convolvulus arvensis*. and *Cyperus esculentus* L., were observed to grow rapidly in MT system. These weeds had deep root systems and/or a perennial growth habit that enabled them to tolerate the MT system. The undisturbed root systems and rhizomes under MT system may have given these weeds a head start at the onset of the rainy season and resulted in greater weed biomass accumulation under MT system than MBT.

**Table 3.** Tillage and hand hoe weeding intensity effect on biomass and density of weeds in maize in 2013/14 season
.

| S.O.V | df | Annual weed density | | | | | | | Perennial weed density | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Total weed dry weight | Total weed number | *Amaranthus blitoides* | *Amaranthus retroflexus* | *Chenopodium album* | *Xanthium strumarium* | *Portulaca oleracea* | *Sorghum halepense* | *Convolvulus arvensis* | *Cyperus esculentus L* |
| Replication | 3 | 2970.612$^{ns}$ | 4.45$^{ns}$ | 4.751$^{ns}$ | 1.562$^{*}$ | 1.582$^{ns}$ | 1.290$^{ns}$ | 0.962$^{ns}$ | 0.138$^{ns}$ | 0.153$^{ns}$ | 0.451$^{ns}$ |
| Tillage | 1 | 263.609$^{ns}$ | 16.402$^{**}$ | 83.154$^{*}$ | 3.835$^{**}$ | 3.010$^{ns}$ | 1.018$^{ns}$ | 0.002$^{**}$ | 3.591$^{**}$ | 2.026$^{**}$ | 16.324$^{*}$ |
| Error | 3 | 1534.822 | 1.863 | 7.075 | 0.126 | 0.926 | 0.742 | 4.010 | 0.033 | 0.033 | 0.732 |
| Weeding intensity | 2 | 290967.051$^{**}$ | 4.595$^{ns}$ | 8.732$^{ns}$ | 1.548$^{ns}$ | 1.149$^{ns}$ | 1.064$^{ns}$ | 0.165$^{ns}$ | 0.810$^{ns}$ | 2.838$^{**}$ | 14.99$^{**}$ |
| Tillage Weeding Intens. | 2 | 120.697$^{*}$ | 3.140$^{ns}$ | 11.990$^{*}$ | 3.145$^{ns}$ | 2.815$^{**}$ | 2.979$^{ns}$ | 4.277$^{**}$ | 1.107$^{*}$ | 0.853$^{**}$ | 18.202$^{**}$ |
| Error | 12 | 776.184 | 2.778 | 3.331 | 1.223 | 0.529 | 0.915 | 0.833 | 0.281 | 0.089 | 0.397 |
| C.V % | | 9.88 | 15.77 | 30.78 | 3.20 | 23.24 | 31.53 | 24.67 | 24.22 | 15.55 | 34.14 |

ns,* and ** represent non-significant and significant at the 5% and 1 probability levels, respectively

**Table 4.** Tillage and hand hoe weeding intensity effect on biomass and density of weeds in maize in 2013/14 season.

| Treatment | | | Annual weed density (No/m$^2$) | | | | | Perennial weed density (No/m$^2$) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Total weed dry weight (g/m$^2$) | Total weed Number (No/m$^2$) | *Amaranthus blitoides* | *Amaranthus retroflexus* | *Chenopodium album* | *Xanthium strumarium* | *Portulaca oleracea* | *Sorghum halepense* | *Convolvulus arvensis* | *Cyperus esculentus L* |
| Tillage | | | | | | | | | | |
| MBT (T1) | 278.63 a | 78 b | 19.95 b | 7.42 b | 7.92 a | 9.00 a | 13.92 b | 3.58 b | 5.08 b | 1.00 b |
| MT (T2) | 285.26 a | 165 a | 69.08 a | 14.00 a | 15.91 a | 12.65 a | 15.25 a | 7 a | 7.83 a | 1.67 a |
| Weeding intensity | | | | | | | | | | |
| No (W0) | 500.5 a | 118 a | 64.63 a | 8.50 a | 7.63 a | 9.90 a | 13.25 a | 6.63 a | 2.50 a | 0.38 b |
| Low (W1) | 149.2 c | 99.6 a | 31.62 a | 11.38 a | 13.13 a | 7.80 a | 14.13 a | 3.12 a | 6.88 a | 1.13 b |
| High (W2) | 196.2 b | 134 a | 37.35 a | 12.25 a | 15.24 a | 14.80 a | 16.38 a | 6.13 a | 10.00 a | 8.50 a |
| Tillage × Weeding intensity | | | | | | | | | | |
| T1×W0 | 504.1 a | 63.5 c | 15.5 c | 6.75 b | 4.25 c | 8.50 ab | 10.75 b | 3.25 c | 3.75 c | 0.50 b |
| T1×W1 | 131.7 c | 83.8 bc | 21.75 bc | 7.00 ab | 7.75 bc | 3.30 b | 15.00 ab | 3.25 c | 3.00 c | 2.25 b |
| T1×W2 | 200.1 b | 96.75 bc | 22.6 bc | 8.50 ab | 11.75 ab | 15.30 a | 16.00 a | 4.24 bc | 8.50 b | 2.25 b |
| T2×W0 | 496.9 a | 172.3 a | 113.75 a | 10.25 ab | 11 ab | 11.30 ab | 15.75 ab | 10.00 a | 1.25 c | 2.25 b |
| T2×W1 | 166.7 bc | 125.5 ab | 41.5 bc | 15.75 ab | 18 a | 12.30 a | 13.25 ab | 3.00 c | 10.75 a | 0 b |
| T2×W2 | 192.2 b | 171 a | 52 b | 16.00 a | 18.75 a | 14.35 a | 16.75 a | 8.00 ab | 11.50 a | 34.75 a |

The means with similar letter in each column are not significantly difference at the P=0.05 level according to Duncan Multiple Range Test.

**Table 5.** Maize yield response to tillage and hand hoe weeding intensity in 2013/14 year.

| S.O.V | df | Maize grain yield | Ear length | Grain number Ear | 1000 grain weight | Maize total dry weight | Harvest index |
|---|---|---|---|---|---|---|---|
| Replication | 3 | 0.155$^{ns}$ | 1.547$^{**}$ | 0.672$^{ns}$ | 240.805$^{**}$ | 0.643$^{*}$ | 172781$^{ns}$ |
| Tillage | 1 | 2.736$^{**}$ | 2.761$^{**}$ | 0.679$^{ns}$ | 147.312$^{**}$ | 6.732$^{**}$ | 1663.903$^{**}$ |
| Error | 3 | 0.019 | 0.003 | 1.038 | 7.118 | 0.057 | 239.830 |
| Weeding intensity | 2 | 2.195$^{**}$ | 2.340$^{**}$ | 0.104$^{ns}$ | 62.670$^{**}$ | 7.151$^{**}$ | 1.949$^{ns}$ |
| Tillage× Weeding intensity | 2 | 0.232$^{**}$ | 0.009$^{**}$ | 0.080$^{ns}$ | 4.649$^{**}$ | 0.764$^{**}$ | 42.921$^{ns}$ |
| Error | 12 | 0.092 | 0.278 | 0.127 | 25.726 | 0.214 | 340.654 |
| C.V % | | 6.61 | 4.33 | 2.30 | 3.17 | 6.58 | 10.76 |

Abbreviations: MBT – mouldboard tillage; MT – disc tillage.

Perennial weeds have been reported to establish rapidly in non-inversion tillage fields in studies [12, 14]. In addition, the weeds *Chenopodium album*, *Amaranthus* sp. and *Portulaca oleracea* L., were observed to quickly regenerate after hoe weeding under wet conditions (Table 4). This suggests that hoe weeding as done in this study was not fully effective in controlling these weeds. It may, in fact, have increased weed infestations when the cut stems gave rise to new weed plants.

MT tillage system had greater weed growth than MBT in the cropping season. This period falls within the first third of most crops life cycle that is required to be kept weed free to avert yield loss [16]. Several investigators, reported a weed-free period of 50 days from seeding for maize in order to prevent yield loss in Mexico [21]; whereas, in the United States they reported a period of 3 to 6 weeks [11]. In the Iran, the CPWC began 20 days after maize emergence and ended 53 days after corn emergence [18]. The high early season weed growth suggests a potential for increased weed competition that would probably necessitate early weed control strategies to be implemented if significant crop yield losses are to be averted.

### *3.2.2. Effect of intensity of hoe weeding*

The tillage **x** weeding intensity interaction showed that The high weeding intensity treatment increased weed density and this translated into significantly ($P < 0.001$) higher weed biomass measured at 7 WAP (Table 3,4). At 4 WAP, low weed biomass was observed (166.7 $g/m^2$) in the low weeding intensity treatment than in high weeding intensity in MT tillage system (Table 4). There was no difference in weed density and biomass at 4 WAP between the MT and MBT tillage systems at the low weeding intensity treatment (Table 4). Similar results were obtained in a field study in Norway where the use of herbicides diminished differences between tillage systems compared to where no herbicides were applied [23]. The high weeding intensity treatment in MBT significantly ($P < 0.001$) reduced total weed biomass (between 4 and 7 WAP) by 4% compared to the high weeding intensity treatment in MT. Weeding two times significantly ($P < 0.001$) reduced weed biomass at 4 and 7 WAP (Table 4). In addition, the plots that had received the high weeding intensity treatment when maize was grown in 2013/14 season had a weed density at 7 WAP that was 24% less than that of the low weeding intensity treatment. When summed over all weed sampling times after maize was planted, the high weeding treatment reduced weed density by 25% and weed biomass by 24% compared to the low weeding intensity treatment.

Thus, frequent hand hoe weeding, as demonstrated in a number of studies throughout Africa [4, 6 and 15], can significantly reduce both weed emergence and growth across the cropping season. It was also effective in reducing early season weed growth in maize grown under MT to the level found in MBT. However, the two hoe weeding carried out in this study may not be a feasible option for the majority of resource-poor smallholder farmers. Bolliger et al. [3] report that the majority of smallholder zero-till (CA) farmers in southern Brazil find it difficult to control weeds without herbicides more than 20 years after replacing ploughing with zero-till. This dependence by zero-till smallholder farmers in Brazil on herbicides for effective weed control is reported to have increased herbicide use by 17% compared to conventional tillage. Consequently, this high weeding demand for MT systems will probably limit the area under these tillage systems in smallholder crop production systems. The requirement for frequent weeding throughout the cropping season is likely to exacerbate the labor constraints faced by the majority of smallholder farmers in Iran. It is, therefore, likely that the area under MT systems will be limited by the difficulty experienced by smallholder farmers in carrying out timely and frequent yearlong weed management over large areas using the labor-intensive hand hoe weeding method.

### *3.3. Crop performance*

MBT had the highest maize ear length, 1000 grain weight, maize total dry weight, harvest index, total maize N uptake, grain N uptake and grain N concentration which translated significantly higher than in MT systems (Table 5,6,7,8). In both tillage systems, there was good maize establishment and growth due to conducive environmental and management conditions. Although the high weeding intensity treatment increased maize grain yield by 0.8%, the yield difference between the high and low weeding intensities was not statistically significant. Mahmoodi and Rahimi [18] found at least two weedings in the first 5 weeks of maize growth to be sufficient to avert yield decline from weed infestation. Hoe weeding in the low weeding intensity treatment was carried out within this critical period. It may, therefore, be difficult to convince smallholder farmers to carry out more weedings later in the season for no additional yield benefit especially for a crop that it is neither a staple nor cash crop. The low maize stand in MT system probably contributed to the low grain yield as maize grain yield at 2013/14 season was positively correlated with maize density. The maize harvest index obtained under MBT was 28% greater than yield under the MT. The high weed biomass at 4 WAP (Table 6) probably reduced components maize yield. On average, the maize crop in this study was observed to had lower ear length and grain number ear in MT tillage (Table 6). Increased weed competition may have reduced ear length and grain number ear and ultimately grain yield. The grain yield obtained under the low weeding intensity treatment was significantly ($P < 0.05$) lower (0.8%) than that obtained at the high weeding intensity treatment (Table 5, 6) indicating the benefits of high weeding intensity on maize yield.

**Table 6.** Maize yield response to tillage and hand hoe weeding intensity in 2013/14 season.

| Treatment | Maize grain yield (t ha-1) | Ear length (cm) | Grain number Ear (no) | 1000 grain weight (g) | Maize total dry weight (t ha-1) | Harvest index (%) |
|---|---|---|---|---|---|---|
| Tillage | | | | | | |
| MBT (T1) | 4.931 a | 12.506 a | 15.664 a | 162.303 a | 7.547 a | 57.865 a |
| MT (T2) | 4.250 b | 11.828 b | 15.328 a | 157.348 b | 6.488 b | 41.212 b |
| Weeding intensity | | | | | | |
| No (W0) | 3.990 b | 11.552 b | 15.383 a | 157.824 c | 5.927 b | 49.687 a |
| Low (W1) | 4.886 a | 12.382 a | 15.611 a | 163.023 a | 7.514 a | 49.140 a |
| High (W2) | 4.925 a | 12.567 a | 15.613 a | 158.628 b | 7.611 a | 49.789 a |
| Tillage× Weeding intensity | | | | | | |
| T1×W0 | 4.351 c | 11.854 bc | 15.619 a | 160.747 b | 6.538 b | 59.361 a |
| T1×W1 | 5.361 a | 12.727 ab | 15.665 a | 165.935 a | 8.305 a | 57.941 a |
| T1×W2 | 5.081 ab | 12.937 a | 15.708 a | 160.225 b | 7.800 a | 56.292 a |
| T2×W0 | 3.628 d | 11.249 c | 15.147 a | 154.900 d | 5.317 c | 40.013 b |
| T2×W1 | 4.372 c | 12.037 bc | 15.558 a | 160.112 b | 6.724 b | 40.338 b |
| T2×W2 | 4.768 bc | 12.197 ab | 15.278 a | 157.031 | 7.423 ab | 43.285 b |

Abbreviations: MBT – mouldboard tillage; MT – disc tillage.

The means with similar letter in each column are not significantly difference at the P=0.05 level according to Duncan Multiple Range Test.

**Table 7.** Maize yield response to tillage and hand hoe weeding intensity in 2013/14 year.

| S.O.V | df | Maize N uptake | Grain N uptake | Grain N concentration | Total maize N concentration | Grain protein yield |
|---|---|---|---|---|---|---|
| Replication | 3 | 11.586 $^{ns}$ | 25.646 $^{ns}$ | 0.001 $^{ns}$ | 0.007 $^{ns}$ | 4589.595 $^{ns}$ |
| Tillage | 1 | 306.142 $^{*}$ | 371.833 $^{*}$ | 0.013 $^{*}$ | 0.008 $^{ns}$ | 15542.691 $^{ns}$ |
| Error | 3 | 32.680 | 34.428 | 0.001 | 0.010 | 2134.358 |
| Weeding intensity | 2 | 643.620 $^{**}$ | 397.371 $^{**}$ | 0.003 $^{ns}$ | 0.000 $^{ns}$ | 8201.103 $^{**}$ |
| Tillage× Weeding intensity | 2 | 104.316 $^{**}$ | 58.301 $^{*}$ | 0.002 $^{ns}$ | 0.008 $^{ns}$ | 299.210 $^{**}$ |
| Error | 12 | 6.008 | 13.265 | 0.001 | 0.003 | 849.880 |
| C.V % | | 3.89 | 7.18 | 3.20 | 6.27 | 10.70 |

Abbreviations: MBT – mouldboard tillage; MT – disc tillage.

**Table 8.** Maize yield response to tillage and hand hoe weeding intensity in 2013/14 season.

| Treatment | Total maize N uptake (kg ha$^{-1}$) | Grain N uptake (kg ha$^{-1}$) | Grain N concentration (%) | Total maize N concentration (%) | Grain protein yield (kg ha$^{-1}$) |
|---|---|---|---|---|---|
| Tillage | | | | | |
| MBT (T1) | 66.530 a | 54.634 a | 1.215 a | 0.883 a | 297.878 a |
| MT (T2) | 59.386 b | 47.762 b | 1.169 b | 0.920 a | 246.982 a |
| Weeding intensity | | | | | |
| No (W0) | 52.606 b | 42.601 b | 1.194 ab | 0.900 a | 228.614 c |
| Low (W1) | 67.842 a | 55.453 a | 1.171 b | 0.903 a | 276.395 b |
| High (W2) | 68.425 a | 54.040 a | 1.210 a | 0.901 a | 302.281 a |
| Tillage× Weeding intensity | | | | | |
| T1×W0 | 54.605 d | 45.733 d | 1.229 a | 0.864 b | 267.929 d |
| T1×W1 | 75.575 a | 62.400 a | 1.197 ab | 0.910 ab | 305.028 b |
| T1×W2 | 69.440 b | 55.770 b | 1.218 a | 0.893 ab | 320.678 a |
| T2×W0 | 50.608 e | 39.469 e | 1.159 bc | 0.954 a | 209.300 f |
| T2×W1 | 60.140 c | 48.507 cd | 1.144 c | 0.896 ab | 247.763 e |
| T2×W2 | 67.411 b | 52.309 b | 1.202 ab | 0.909 ab | 283.883 c |

Abbreviations: MBT – mouldboard tillage; MT – disc tillage.
The means with similar letter in each column are not significantly difference at the P=0.05 level according to Duncan Multiple Range Test.

## 4. Conclusions

MT system were found to have higher weed growth than MBT in maize. This would require early and more frequent weeding that is likely to exacerbate existing labor bottlenecks in smallholder crop production systems. Overall weed growth was decreased and crop grain yield improved with increasing hand hoe weeding intensity irrespective of the tillage systems. However, most smallholder farmers lack sufficient labor to carry out the two hoe weeding as done in this study. Low grain yield was realized in MT system probably due to poorer crop establishment compared to MBT. In order for MT to be practiced on a large area by smallholder farmers, there is need for research on the economical feasibility of using herbicides for early season weed control.

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