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Soil penetration resistance and time required for corn seedbed preparation under four tillage systems

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In order to measure soil cone index and time required for corn seedbed preparation in different soil moisture contents at Darab Agricultural Research Center, Fars province, Iran, three moldboard and one chisel plow-based tillage systems were conducted and the results obtained were compared. The ground speed, efficient field capacity etc., were measured in each primary and secondary tillage operation. Cone index was also measured in each treatment. Based on the results, soil moisture content particularly affected the primary tillage operations and had a significant effect on both implement performance and soil cone index. The highest, 6.75hr.ha^{-1}, and lowest, 2.74hr.ha^{-1}, values of field capacity amid the systems mentioned above were obtained by a moldboard plow with 8.65% moisture content of soil, and applying a chisel plow with 16-18% soil moisture content respectively. The comparison of the soil cone index affected by four different treatments of the tillage performed for corn production indicated a significant difference in 0-24cm depths at a 1% significance level and also the minimum and maximum values of cone index obtained were 795.4 kPa, and 1054 kPa related to soil preparation by a moldboard and soil moisture content of lower than 10% and a chisel plow with 16-18% moisture content of soil, respectively.

Key words: tillage, efficient field capacity, soil cone index

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Introduction

Nowadays, an increase in agricultural productions is obtained generally by overusing the inputs in different agricultural operations and consuming noticeable amount of energy. With regard to tillage as an important agricultural operation for seedbed preparation, researchers have shown that such an operation uses as high as 90% of the whole energy consumed in farm during the agricultural operations (Bolach *et al*., 1991). On the other hand, heavy tillage operations besides consuming more amount of energy, decreases the soil organic matters while reduction of tillage operations bring about the increase of soil organic matters by returning more plant residues to soil and causes a better balance of it (Tisdall and Oades, 1982). Increased soil organic matters, commonly present in conversation tillage systems may lead to reduced effects of soil compaction (Thomas *et al*., 1996). Higher levels of organic matters may also lead to water increase in soil profile provided for crops during the growing season (Hudson *et al*., 1994). Moreover, the higher the number of tillage operations is, the lesser amounts of plant residues are kept on soil surface and as a result not only soil erosion but also environmental pollutions increase (Radcliffe *et al*., 1988). Hence, choosing the right implements and using the efficient methods of tillage practices can lead to reduction of production costs, protection of natural resources and more time is saved per operation. Soil moisture content is an important factor which has great effects on drag and the plowing quality. The dryer the soil is naturally more power is required to pull the implements (Borid *et al.*, 1997). Michel and John Borrelli (1985) through a series of farm experiments, compared the application of chisel and moldboard plows for sugar beets, dry beans, and corn bed preparation. In different methods of farming, they measured the ground speed, wheel slippage, time for performing the operations and the crop yield. The results showed that duration needed for performing the tillage operation by a chisel plow is less than that of the same operation by a moldboard plow while the ground speed has increased during the former operation compared with the latter. To evaluate the energy requirement and compare the efficiencies of the moldboard plow, chisel plow, offset and tandem disks, through some experiments conducted by Bowers (1986) parameters such as ground speed, draft force and fuel consumption were measured. Based on his achievements, fuel consumption and the time needed for each operation, in each treatment, is higher for the moldboard plow-based operation compared to chisel and the two other disks. Soil cone index (CI) is an empirical measure of soil strength and is widely used for assessment of the compacting and loosening effects of agricultural implements (Be´dard *et al*., 1997). Soil compaction continues to be a challenge to agricultural productions particularly since some of the large field machines have axle loads in excess of 10 T per axle (Schuler and Wood, 1992; Soane and vanQuwerkerk, 1994; Johnson and Bailey, 2002; Borghei *et al*., 2008). Soil CI is also used to assess root growth and propagation. As the CI increases, more energy is needed by the root to widen the soil pores (Gerard *et al*., 1982). The threshold level at which soil strength hinders root elongation varies with plant species, but usually ranges between 2000 and 3000 kPa (Atwell, 1993). Letey (1995) reported a lower threshold value (1800 kPa).

The study objective was to measure soil cone index and time needed for corn field preparation in different soil moisture contents at Darab Agricultural Research Center, Fars province, Iran. Therefore, three moldboard and one chisel plow-based tillage systems were conducted and the results obtained were compared.

Materials and methods

In this study, for measuring the parameters needed, a MF 399 tractor was used and the specifications of the implements are brought in Table 1. Having access to the distance between the start and stop points of the travel and measuring the time needed to cover it, the average of forward speed was calculated. Some soil samples were taken from corn fields, and based on those, the trial fields were chosen. After choosing and partitioning of the trial field, making plots, some days before the beginning of the experiments, all the experimental plots were irrigated and their moisture percent values were measured in 0-25 cm depths daily. After moisture reduction, the experiments started in moisture content ranging from 16 to 18% as well as lower than 10%. In each experiment, some fields were chosen and their moisture contents, during the operation, were measured. The investigations indicated that in the region some fields were plowed in 16-18% moisture contents while some others, due to the lack of implements were prepared in 10% moisture content. In the latter, the farmers due to the shallow depth of the primary plowing and the big clods in result, traditionally would plow their fields for the second time and for reaching a proper seedbed they were obliged to disk their fields two or three times. Three treatments of corn bed preparation by a moldboard plow like the traditional ways in the region were conducted in the specific moisture contents and the proposed treatment was the one that included a chisel plow conducted in 16-18% moisture contents. As mentioned above, this experiment was conducted in Darab Agricultural Research Center, Fars province, Iran (longitude: 45°28, latitude: 54°32). The altitude of the region is also 1160 m above sea level, and the chosen field was wheat planted. For determining the soil texture, some samples were chosen from field depths of 0-30cm randomly. The soil texture was classified as clay loam. For conducting this research, we went through a 4 treatment-5 replication randomized complete block design. The followings constitute the treatments:

Application of a moldboard plow and a leveler each one time and a disk for two times (I).

Application of a moldboard, a disk, and a leveler each one time (II).

Application of a moldboard, a disk each two times and a leveler for one time (III).

Application of a chisel, a disk, and a leveler each one time (proposed treatment or IV).

Table 1. Specifications of the equipment.

	Implement	Weight (kg)	Specifications
1	Moldboard plow	375	Mounted type, three bottoms, 35 cm bottom width
2	Chisel plow	450	Mounted type, 9 shanks, 2 rows, 30 cm shank spacing, 7 cm tool width
3	Tandem dish harrow	830	Drawn type, 28 disks, 7 disk per gang, 50 cm disk diameter, 18 cm disk spacing
4	Leveler	845	Drawn type, 280 cm blade width, 300 m back leveler length

The moisture content during the primary tillage operation of I, II and IV varied between 16-18% but for the III was less than 10%. In III, disk operation was performed after plowing while in I, II and IV it started when the soil moisture content decreased to 10-13%. Leveling was the same for all treatments. For each treatment efficient field capacity and soil CI and crop yield were measured. Four central rows in each plot were harvested to record crop yield. Each experimental plot was 50 m long and 10 m wide and the distance between two adjacent plots was 3 m. A penetrometer (Sp- model 1000) was pushed into the soil at a speed of approximately 30mm.s^{-1}. The cone penetrometer would alarm if the penetration speed of the cone would exceed 50mm.s^{-1}. Based on the ASAE standard, the cone apex angle was 30° and its big and small diameters were 12.83 and 20.27mm respectively. It also was equipped to a built-in data logger which would record the measurements. CI was calculated by the Eq.(1),

$$CI = \frac{F}{A} \quad \text{………………………………………………..(1)}$$

Where CI is the cone index (KPa), F is the average of recorded forces (KN), and A is the CI base area (mm^2). For measuring the efficient field capacity of the implements used on each plot, the total duration for each implement was measured with a chronometer and consequently calculated the efficient field capacity, Eq.(2),

$$F_{ce} = \frac{A}{T_t} \qquad \text{……………………………………………(2)}$$

Where F_{ce} is the efficient field capacity (ha.hr^{-1}), A is the area (ha) and T_t is the total time (hr). Eventually, we performed the analysis of variance (ANOVA) of the data collected from field trails (by MSTAT Software) and we went through the Duncan's multiple ranges test to compare our treatment averages.

Results and discussion

In this study, we used some parameters measured such as efficient field capacity, ground speed, soil CI and the crop yield to compare the different ways of corn seedbed preparation. Table 2 shows the comparison of efficient field capacity averages, durations of plow operations and the ground speed at 5% significance level (Based on Duncan's multiple ranges test). As we see, plow operation performed by a chisel plow is done sooner compared with three other moldboard plow-based operations and this comes from more working width and higher speed of the chisel (Michel and John Borrelli, 1985). For finding the effect of soil conditions on disk performance, prior to disking operation, parameters such as speed, field capacity and the time per operation were calculated and analyzed (Table 3). It is concluded that disk harrow application on plots plowed by a chisel (IV), has taken less time per unit area compared with disk operation in other treatments. The reason is attributed to be the existence of smaller clods as the result of chisel plowing and less soil disturbance. The same results were reported by Michel and John Borrelli (1985) and Bowers (1986). Furthermore, it is found that when bed preparation is performed by a moldboard plow in moisture content of 8.65% (III), plowing and wheel slippage lead to big clods and consequently disk operation which follows plowing takes longer. Table 4, shows the comparison of averages of ground speed, efficient field capacity and time per unit area for leveling operation which its results are similar to the previous comparisons. Comparing different operational systems is based on the crop yield, total time, and the total number of operations. Based on the analysis of variance of these parameters it is perceived that there is a big significant difference among the total time while tillage treatments have not statistically had any remarkable effect on crop yield. Comparing the averages of the treatments (Table 5) indicates that IV in comparison with II has saved 1.11 hr per hectare and also treatment III which its primary and secondary tillage operations are performed in low moisture contents required 6.75 hr per hectare. Moreover, the response of corn 704 cultivar to clod formation with different aggregate diameters and mean weight diameters has been the same in all beds.

Table 2. Comparison of the averages of field capacity, ground speed and time required for primary tillage implements.

Primary tillage implements	Ground speed (km/hr)	Field capacity (ha/hr)	Time per hectare (hr/ha)
Moldboard plow (treatment I)	5.28[a]	5.27[b]	1.99[a]
Moldboard plow (treatment II)	5.29[b]	0.512[b]	1.95[a]
Moldboard plow (treatment III)	5.54[b]	0.534[b]	1.87[a]
chisel plow (treatment IV)	6.17[a]	1.022[a]	0.98[b]

The averages labeled with the same alphabet in each column, based on Duncan's multiple ranges test, statistically do not have any significant difference at 5% significance level.

Table 3. Comparison of the averages of field capacity, ground speed and time required for disk harrow through different methods.

Secondary tillage implements	Ground speed (km/hr)	Field capacity (ha/hr)	Time per hectare (hr/ha)
Disk harrow after Plowing by a moldboard plow (treatment I)	7.288[a]	1.090[a]	0.92[b]
Disk harrow after Plowing by a moldboard plow (treatment II)	7.344[a]	1.156[a]	0.86[b]
Disk harrow after Plowing by a moldboard plow (treatment III)	6.598[b]	0.924[b]	1.08[a]
Disk harrow after Plowing by a chisel plow (treatment IV)	7.458[a]	1.176[a]	0.85[a]

The averages labeled with the same alphabet in each column, based on Duncan's multiple range tests, statistically do not have any significant difference in 5% significance level.

Table 4. Comparison of averages field capacity, ground speed and time rquired for leveler, through different tillage methods.

Secondary tillage implements	Ground speed (km/hr)	Field capacity (ha/hr)	Time per hectare (hr/ha)
Leveler (treatment I)	5.572[a]	1.016[a]	0.98[b]
Lever (treatment II)	5.016[b]	0.984[b]	5.618[a]
Leveler (treatment III)	5.026[b]	0.8[c]	1.25[a]
Leveler (treatment IV)	5.886[a]	1.2[a]	0.83[c]

The averages labeled with the same alphabet in each column, based on Duncan's multiple range tests, statistically do not have any significant difference in 5% significance level.

Table 5. Comparison of the time averages and crop yield in different tillage methods.

Quantities	Tillage methods			
	Treatment I	Treatment II	Treatment III	Treatment IV
The number of operation	4	3	5	3
Total time required per hectare (hr/ha)	4.49^{b}	3.85^{c}	6.75^{a}	2.74^{d}
Crop yield (ton/ha)	8.84^{a}	9.16^{a}	8.49^{a}	9.17^{a}

The averages labeled with the same alphabet in each row, based on Duncan's multiple range tests, statistically do not have any significant difference at 5% significance level.

Table 6. Comparison of soil CI averages through different tillage methods, based on Duncan's multiple ranges test (KPa).

Tillage method	Depth (cm)			
	0-21	0-24	22-50	25-50
treatment I	851.8^{ab}	912.5^{ab}	1575^{a}	1603^{a}
treatment II	856.6^{ab}	917.4^{ab}	1576^{a}	1603^{a}
treatment III	719.4^{b}	795.4^{b}	1573^{a}	1601^{a}
treatment IV	999.9^{a}	1054^{a}	1625^{a}	1648^{a}

The averages labeled with the same alphabet in each column, based on Duncan's multiple range tests, statistically do not have any significant difference at 5% significance level.

Therefore, if Darab, Fars corn producers use the chisel plow (IV) instead of I and II treatments for bed preparation, less time per unit area is required. It also causes that the series of fields which should be prepared in less than 10% moisture content (III) can be tilled in proper moisture and soil erosion deceases noticeably. The method IV also reduces the costs while the crop yield dos not vary significantly. Table 6, shows the comparison of soil CI averages in different depths and moisture content of 19.64%. Based on the Table 6, it is concluded that the effects of different bed preparation methods on soil CI is up to 25cm depth. Table 6, also shows the comparison of soil CI averages in different depths and moisture content of 19.64%. According to the comparison of averages, we got that field preparation in low moisture contents (III), despite more number of implements and tractor passes but conducting the primary and secondary tillage operations in lower moisture contents (<10%), has gained the lowest CI to depth of 25cm. Although primary tillage operation in moisture contents ranging 16-18%, leads to CI increase, up to 25cm, in I and II compared with the III, but they don't have any significant difference statistically. The results also indicate that effect of moisture content percentage and the number of tillage operations on CI, is more in plowed depth of region, because there isn't any difference among the cone indices in deeper layers at 5% significance level. Bueno *et al*. (2006) showed that CI at 15 cm depth decreased with moisture content under both no-tillage and conventional tillage systems, and that for a given moisture content, CI under no-tillage is higher that that under conventional tillage system.

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