

Effects of Tillage Methods and Sowing Rates on the Grain Yields and Yield Components of Rain Fed Wheat

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ABSTRACT

A field study was conducted on the effect of four primary tillage implements and three seed densities on the grain yield of rain fed wheat (Tajan cultivar), using a drill planting machine with the end wheels. The experimental design was a split plot design in a 4×3 factorial with three replications. In this study, the main plots were the tillage treatments, namely Mouldboard plough, Disc Plough, Chisel Plough, Offset Disc, and sub-plots were seed rates of 350, 400 and 450 seeds.m⁻². Determinations included grain yield and selected yield components. The results showed that grain yield was not affected by the densities of seed and tillage machine treatments. The use of Chisel Plough, with 400 seeds.m⁻² sowing rate, had the highest grain yield of wheat grown in the Golestan province (Iran), a region with an average annual rainfall of 450 mm.

Keywords: Seed rate, tillage, wheat, yield, planting density

ABBREVIATIONS

- T.M. = Tillage Machine
M.P. = Mouldboard plough
D.P. = Disc Plough
C.P. = Chisel Plough
O.D. = Offset Disc
S.R. = Sowing Rate
M.H. = Mean Height
M.S.S. = Mean no. of seed or kernel in each spike or cluster
W.P. = Weight of product in each plot
G.Y. = Grain Yield
M.S. = Mean Squares
W.P. = weight of product/crop in each plot

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INTRODUCTION

The bread supplied from the wheat is prevailing food which is highly used by the population in Iran. Therefore, there is a need to increase wheat production to meet the local food demand. Most researches conducted in Iran have focused mainly in the field of genetic and less work has been carried out on discovering or improving technical and production systems such as sowing rate, application of tillage implements, and planting. Thus, research on the tillage methods is very important because it utilizes 60% of the consumed energy in agricultural practices (Iqbal *et al.*, 1994).

The purposes of tillage are to create an appropriate environment for germination of seed, growth of stem, weed control, preservation of soil moisture and stabilization of soil to ensure good seed contact with soil, reduce soil erosion, burying vegetative debris or vestiges, mixing of fertilizers, fungicides, herbicides, pesticides, as well as reforming materials with soil and unsettling soil capillary pipes to reduce evaporation (Mansoori Rad, 2005). To achieve these objectives, certain tillage implements had independently been applied based on a given situation. However, if appropriate machine is not used, it can lead to soil compaction, development of hardpan and degradation of soil which may finally lead to yield reduction and increase of the mechanization costs (Hargrave *et al.*, 1982). However, in most subculture lands in Iran, crop production without proper tillage practice does not have satisfying results (Hemat and Asadi, 1997).

Similarly, for every climate and region, appropriate seed density varies with agro-ecology. Seed density (sowing rate) has been shown to have important effect on the final yield. In specific, if seed density is less or more than the optimal rate, it will lead to a yield reduction. For instance, when the seed rate is more than the optimal amount, the grains or kernels will become weak and shrinkage, and this will consequently lead to lower yields.

Among the three yield components, heads per unit area and kernel per head are considered as more important than kernel weight in determining wheat grain yield (Donaldson *et al.*, 2001; Schillinger *et al.*, 2005). Heads per unit area is generally the most important yield component for wheat (Garcia Del Moral *et al.*, 2003), but under drought conditions, kernel per head often has the greatest effect on grain yield (Arnon, 1972; Schillinger and Young, 2004). High sowing rates often result in the increase in the head per unit area (Guberac *et al.*, 2000; Stougaard and Xue, 2004), with a corresponding reduction in the kernel per head (Carr *et al.*, 2003). In relation to the increasing sowing rate, the number of plants will generally rise, but the yield per area unit will not be increased because of the mentioned reason (Paulsen, 1987).

The most widely recommended sowing rate for dry land spring wheat in the northern Great Plains and the Pacific Northwest is 200 seeds.m⁻² (Paulsen, 1987), but some farmers sow up to 350 seeds.m⁻². Considerable variability in optimum sowing rate for cereals often involves interaction effects with tillage, cultivar and environmental factors. The common sowing rate for dry land spring cereals, in the less than 300 mm annual precipitation zone of the Pacific North west, is 195 seeds.m⁻². Sowing rate as high as 800 seeds.m⁻² has been reported for oat production in Finland (Peltonensainio and Jarvinen, 1995). In particular, the sowing rate of rain-fed wheat in the north of Iran is subject to change, and depends on the climate condition and based on weight of 1000 kernel or seed, is between 100 to 250 kg.ha⁻¹.

A study conducted by Touchton and Johnson (1982) showed that the yield of soya bean was not affected by the tillage methods but the yield of wheat in the chisel ploughed plot was found to be less than the mouldboard ploughed plot. It was therefore suggested that the soil should be ploughed using mouldboard or chisel plough before planting, since the yield is better than no tillage. Cox (1986) studied the effects of different methods of soil preparation, under two different types of wheat seed on the yield. However, no significant difference was reported in the yield among all

the treatments. Baloch *et al.* (1991) compared the yields in the farm ploughed with implements like mouldboard plough, disc plough, chisel plough and cultivator. The results showed that the disc plough required more tension strength in loam–clay soil as compared to the loam-silt. They also reported that the product yield of the farm ploughed by cultivator was increased by 48.5% when compared to when the Mouldboard Plough was used and 59.1% when compared with the Disc Plough.

Lal (1981) suggested that no tillage system should be recommended if no tillage system was found to have any considerable effect relative to other tillage systems in tropical countries because this system decreases the mechanization cost. To achieve the desired conditions of the crop, mechanical operation was carried out on the soil. Arvidsson and Feiza (1998) reported that tillage operation, using mouldboard plough and chisel plough, showed a significant effect on the tensile tolerance of silt-clay Swedish soil. Several researches carried out in Denmark showed that the compaction of subsoil was a general problem (Schjenning and Rasmussen, 1998; Schjenning *et al.*, 2001; Djurhus and Olesen, 2000). Meanwhile, Perfect and Kay (1994) and Macks *et al.* (1996) reported less tensile tolerance for the soil under minimum tillage as compared to the soil tilled with conventional method. One of the reasons for the increase of soil tensile tolerance is soil compaction as a result of using tillage machines. According to these studies, very strong compaction is often found under the plough layer. For instance, Schjenning and Young (2004) showed that conventional land preparation machines usually cause compaction of subsoil.

The field experiments by Khosravani *et al.* (1995) showed that ploughing of one hectare of land using the Mouldboard Plough utilized more fuel compared to the Chisel Plough, while the field capacity of latter was about two times as much. The main objectives of the primary tillage operation are unsettling the soil compaction and root growth. The soil compaction causes reduction of the moisture and oxygen penetration inside the soil and increasing energy consumption (Tebrugge, 2002). Tillage operation has an influence on the physical properties of soil structure (Hamblin and Tennant, 1987) and it will reform specific gravity of dry soil, apparent tolerance, thermal conductivity, water distribution, porosity distribution, root distribution and crop yield (Lal *et al.*, 1994).

The study by Raoufat and Matbooei (2007) on the two methods of ploughing, namely disking followed by Chisel Plough and disking ahead of a planter, showed that equipping available planters with row cleaners was successful in reduced tillage corn production system. In addition to the environmental benefits, it also has advantages such as saving time, fuel and labour. Improved infiltration of rain water into the soil potentially increases water availability to plants, reduces surface runoff and improves ground water recharge (Lipic *et al.*, 2005). Reduced soil cultivation decreases energy requirements and overall farming costs as less area needs to be tilled (Monzon *et al.*, 2006). The investigation by Qin *et al.* (2006) showed that up to 80% of maize roots could be concentrated in the 0-30cm layer under no tillage systems. The sharp decline in soil water in sandy soil could also be attributed to the drainage out of the sampling depth. The conservation tillage (no till and reduced tillage) practices simultaneously conserve soil and water resources, reduce farm energy usage and increase crop production. These practices lead to positive changes in the physical, chemical and biological properties of soil (Bescansa *et al.*, 2006). The physical properties of soil which are influenced by conservation tillage include bulk density, infiltration and water retention (Osunbitan *et al.*, 2004).

This study was carried out to determine the effects of different primary tillage methods on the grain yield and selected yield components of Tajan wheat variety and to identify the optimum seed rate of Tajan wheat variety using drill planting with end wheels (Danish) in the Gonbad rain fed region of Iran.

MATERIALS AND METHODS

Experimental Site

The experiment was conducted in a research farm of Gonbad Agricultural Faculty, Golestan Province, Iran, during 1997-2000 cropping season on a silt clay loam (64% silt, 30% clay, 6% sand) soil type with an electrical conductivity (EC) of $1.5 \mu\text{m}^{-1}$ and acidity (pH) 7.8. Experimental site is located on the southeast of the Caspian Sea with longitude $37^{\circ}, 20' \text{N}$, latitude $55^{\circ}, 25' \text{E}$ and an altitude of 160 m above the sea level. This region, as characterized by the Ambrotermic meteorology records, enjoys the Mediterranean climate condition. The average annual rainfall of the experimented region is more than 450 mm. Rainfall occurs mainly in autumn, winter and early spring (September to April and May). Meanwhile, the average annual temperature of the region is 17.7°C .

Experimental Layout

The experimental design was arranged with a factorial treatment consisting four primary tillage machines, namely mouldboard plough (MP), disc plough (DP), chisel plough (CP) and off-set disc (OD), with equal ploughing depth of 25 cm and three seed rates (350, 400, 450 seeds. m^{-2}). The plots were pegged out in October for the first year of the experiment and then maintained in the subsequent years. The treatments were set up in a split-plot design with three replications done each year. The main plot factors were allocated to the tillage machines (with an area of $4 \times 18 \text{ m}$ for one treatment excluding the borders). The seed density factor, at three levels, was allocated in the sub-plots (with an area of $6 \times 16 \text{ m}$ for each treatment excluding the borders in one replication). Each plot was separated by a small rotary cultivator with 1 m working pathway or border to avoid interaction effects of the treatments of one plot with the next when crop was growing.

Soil moisture was about 20% (dry basis) based on the soil texture at the time of ploughing and at the end of ploughing. A tandem disc (conventional disc harrow) was applied on the already ploughed plots. Planting was carried out with equal planting depth of 3-5cm and with three seeding rates using a drill planting machine with end wheels (Danish) having 21 rows with 12cm between crop rows.

A MF285 tractor (Massey Ferguson) was used to provide the pulling power. Tajan wheat seed variety, a domestic high producing rain-fed cultivar with 13-16% moisture content, was used in this experiment. Percentage purity, germination and weight of 1000 seeds were 100%, 95% and 39 g, respectively. To prevent fungal diseases or hidden apparent smut, carboxin and vitavax fungicide poisons were used at the rate of 150 gr per 100 kg seed. Planting depth was approximately 3cm at the tractor forward speed of 8-10 $\text{km} \cdot \text{h}^{-1}$. Seeding practice was carried out immediately, i.e. after the preparation of soil (late December to early January). Crop protection practices containing weeding, controls of pests and diseases, as well as chemical fertilizers were applied, based on the soil analysis. Phosphate fertilizer of $100 \text{ kg} \cdot \text{ha}^{-1}$ was applied while planting, and this was followed by $75 \text{ kg} \cdot \text{ha}^{-1}$ while top-dressing carried out in the month of March.

After top-dressing or digitising until the growth of main stems (20-25 cm), weeds were controlled using herbicides; $100 \text{ g} \cdot \text{ha}^{-1}$ Granestar and 1 lit. Pumasuper applied by motorized back sprayer. The amount of the herbicide used was determined based on weed densities and the type of the Sprayer. It was 1-1.5 litres of weedicide with 200-400 $\text{lit} \cdot \text{water} \cdot \text{ha}^{-1}$. Two litres of zineb poison in 1000 litres of water was applied using a sprayer in crop maintenance.

Data Collection

During harvesting time, grain yield and some of yield components, such as mean height, weight of 1000 kernel, mean number of seed in each cluster and weight of crop, were measured from each plot. Time of harvest (the moisture content was 14-16%, leaves were yellow and seeds were firm) was determined in the late spring season. After deletion of the borders, 8 m² from each plot was cut using scissors from the under mast level, put in gunny sacks which had been labelled accordingly and transferred to the Agricultural Research Centre of Gonbad for threshing using a small and special combine machine. The yield at each m² and at each hectare was finally determined using the following equation:

$$H = b \times s \times w \times 10000$$

Where

H=The yield per hectare, b= average number of bunch per m², s= average number of seeds in each bunch, and w= average weight of a seed.

Before harvesting, a 0.25 m² area at the middle of each plot was chosen for determining some yield components such as mean height, weight of 1000 kernel in each plot, mean number of seed in each cluster and weight of crop in each plot, and grain yield of wheat, at each square meter and for each hectare.

Statistical Analysis

The effects of tillage machines and seed rates, on grain yields and some yield components, were evaluated. Tillage machines and seed rates were the sources of variations when the grain yield and yield components of the rain-fed wheat were analyzed. Mean squares of the treatments were obtained using the least significant difference (LSD) or the Duncan multiple test at $p < 0.05$. On the other hand, the probability levels of 0.001, 0.01 and 0.05 were considered to determine the level of significance between the treatment means.

RESULTS AND DISCUSSION

Seasonal Rainfall and Parameters

The results presented in Table 1 indicate that there was a significant difference in the grain yield of the rain-fed wheat between the cropping years. The average annual precipitation in the first cropping year of the experiment (1997–1998) was 593.4 mm and this was 369.2 and 582.3 mm for the second and third cropping years, respectively. The average annual rainfall, in the first and third year of experiment, was higher than the average annual rainfall in the long-term (450 mm), while the rainfall during the second year of experiment was lower, and the distribution of rainfall was uniform. The amount of precipitation and having fallow of research farm before the first year of conducting the experiment led to significant differences ($p < 0.01$) in terms of grain yield of the rain-fed wheat within the three years of conducting the experiment. The remaining residues or stubbles in the second and third years of the experiment, the irregular distribution of rainfall throughout the growing season of the third year of the experiment might have some effects on the grain yields.

Fabrizzi *et al.* (2005) reported that the scarce and poorly distributed precipitation during the growing season could negatively affect the growth and yields of corn and wheat. However, soil water storage was greater under no-tillage (chemical weed control during the fallow period and seeding directly into the standing residues of the previous crop) than under the minimum tillage

TABLE 1
Comparison of the mean grain yield of the rain-fed wheat and the amount of rainfall
with regard to different years

Amount of rainfall (mm)	Amount of grain yield (kg/ha)	Year
593.4	4664.1 a	1997 – 1998
369.2	3554.8 b	1998 – 1999
582.3	2364.5 c	1999 – 2000

Means followed by different letters within a column are significantly different at $p < 0.01$

(chisel plough and two disking). It means that the tillage operation had affected the soil storage capacity which could consequently lead to a reduction in the growth and yields of corn and wheat. The conservation tillage such as using chisel plough during soil preparation leaves most or parts of the crop residues on the soil surface, thus affecting the chemical, biological and physical properties of soil.

The replication treatment was found to produce a significant effect on the grain yield ($p < 0.01$) and weight of crop ($p < 0.05$). This result could be attributed to the prepared conditions of the climate and unsuitable distributed precipitation during the growing season (heavy rainy at two times). In this condition, disc plough for land preparation with 400 seeds.m⁻² plant density were indicated to be slightly better than the others.

Meanwhile, changes in the physical properties of soil, due to using no-tillage, are dependent on several factors including differences in soil properties, weather conditions, history of management, intensity and type of tillage (Mahboubi *et al.*, 1993).

Grain Yield and Other Inspected Characteristics/Parameters

In this study, the type of tillage machines (Table 2) had no significant difference on the grain yield of the rain-fed wheat ($p > 0.05$). However, its effects on the weight and the mean number of 1000 seeds in every spike were significant at 5% and 1% levels, respectively. This could be attributed to the role and nature of the tillage implement in the preparation of soil, but the factors such as its interaction effects within cultivar and environment could also be affected (Paulsen, 1987). Although disc plough prepared the soil at the better conditions related to others and affected the number of seeds in the cluster ($p < 0.01$), it had not affected the grain yield significantly. Garcia Del Moral *et al.* (2003) reported that the number of spikes per unit area was generally the most important yield component for wheat, but under drought conditions, kernel per spike or cluster often has the greatest effect on grain yield (Arnon, 1972; Schillinger and Young, 2004). This result contrasts the result of the present study, largely because of the fact that the experimental site condition was not under drought conditions.

Chisel plough with one time of disking harrow prepared a better seedbed as compared to other methods. It shows an increase in grain yield up to 2.5% compared to the mouldboard plough, 3.3% with the disc plough and 4.5% with the offset disc. The chisel plough normally needs less pulling power or tensile strength, and therefore it can be used at higher speeds, in addition to its capacity to cover a wider area as well (field capacity). Other advantages include energy saving, better fuel consumption and time for the soil preparation (Mansoori Rad, 2005).

TABLE 2
Analysis of variance for different factors within three years of experiment

Resources of variations	G.Y. (Kg.ha ⁻¹)		W. 1000 S. (gr)		W.P. (gr)		M.S.S.		M.H. (cm)	
	F value	M.S.	F value	M.S.	F value	M.S.	F value	M.S.	F value	M.S.
Year	10.97 **	1.4×10 ⁷	1.66 ^{ns}	5.91	3.58 ^{ns}	1.19	0.92 ^{ns}	11.75	0.0001	0.01
Replication	8.76 **	1.2×10 ⁷	2.31 ^{ns}	8.02	4.78 *	1.49	0.63 ^{ns}	8.07	1.69 ^{ns}	31.11
T.M.	0.11 ^{ns}	121757.2	2.96 *	11.13	0.77 ^{ns}	0.26	5.24 **	88.99	1.06 ^{ns}	89.75
S.R.	0.63 ^{ns}	712374.9	0.58 ^{ns}	2.17	0.85 ^{ns}	0.29	0.71 ^{ns}	12.13	1.04 ^{ns}	88.57
T.M. × S.R.	0.31 ^{ns}	356530.2	1.13 ^{ns}	4.24	1.662 ^{ns}	0.56	0.93 ^{ns}	15.87	1.25 ^{ns}	106.57
Error	—	1134363	—	3.76	—	0.34	—	16.99	—	85.06

** significant at 1% level. * significant at 5% level. ns not significant.

T.M. = tillage machine, S.R. = sowing rate, M.H. = mean height,

M.S.S. = mean no. of seed in each spike, W.P. = weight of product in each plot,

G.Y. = grain yield, M.S. = mean squares, W.P. = weight of product/crop in each plot.

TABLE 3
Comparison between the mean treatments for 3 years

Tillage machine	G.Y. (Kg.ha ⁻¹)	W. 1000 S. (gr)	W.P. (gr)	M.S.S.	M.H. (cm)
M. P.	3530 ^a	34.29 ^{ab2}	2.46 ^a	23.89 ^{a1}	70.69 ^a
D. P.	3500 ^a	33.47 ^a	2.71 ^a	29.14 ^c	74.08 ^a
C. P.	3619 ^a	33.36 ^a	2.65 ^a	27.45 ^{bc}	72.65 ^a
O. D.	3461 ^a	35.04 ^a	2.49 ^a	26.02 ^{ab}	68.80 ^a
Sowing Rate (seed. m ⁻²)					
350	3577 ^a	34.35 ^a	2.47 ^a	26.74 ^a	72.96 ^a
400	3637 ^a	34.02 ^a	2.69 ^a	27.23 ^a	73.15 ^a
450	3369 ^a	33.75 ^a	2.56 ^a	25.87 ^a	69.61 ^a

Means between treatments followed by similar letters do not differ significantly ($p>0.05$)

1. Means between treatments followed by different letters differ significantly $p<0.01$

2. Means between treatments followed by different letters differ significantly ($p<0.05$)

MP = mouldboard plough, DP = disc plough, CP = chisel plough, OD = offset disc

The reports by French and Schultz (1984) and Barzegar *et al.* (1984) proved the same gained results. Tanaka (1989) compared the yield of peas using the tillage methods including no tillage, reduced tillage and mouldboard plough (the current method), and they concluded that the difference in the yield with the mentioned tillage methods was not significant, and that no tillage method showed trend towards more yield. Ciha (1982) reported that ploughing done using the chisel plough had greater yield as compared to other tillage methods for the production of wheat. Similar results were reported by Hodgson *et al.* (1989). Afuni and Mosaddeghi (2001) and Mahboubi *et al.* (1993) recommended the applications of either of the two methods of soil preparation, i.e. chisel plough or disc plough. However, other researchers found that mouldboard plough had significant effects on the yield of irrigated wheat when compared with other tillage methods (Hemat and Asadi, 1997).

Nevertheless, seed density factor did not show any significant effect ($p>0.05$) on the grain yield and yield components of the rain-fed wheat (Table 2). This result could be due to the low interval of sowing rates. Although seed density or sowing rate did not show any significant effect on the grain yield and yield components of the rain-fed wheat, the comparison of the average yield of the rain-fed wheat with different seed densities (Table 3) showed that the rate of 400 seeds.m⁻² produced more yield, and this was followed by 350 seeds.m⁻² (~2% decreasing crop) and 450 seeds.m⁻² (7% decreasing crop). This could be attributed to the deficit of soil nutrition and moisture with bush increase, decrease in the number of spikelet into the spike of wheat in the plots of high sowing rates, and the shortage of seeds per area unit in the plots of low sowing rates. Therefore, the recommended seed rates were between 400 seeds.m⁻² ~ 150 kg.ha⁻¹ to reduce production costs. Khajehpoor (1986) found similar results in the seed densities of 70, 100, 150 kg.ha⁻¹, and he recommended 100 kg.ha⁻¹. However, Seif (1975) in his report showed that seed density had no significant effect on the grain yield of the product, but recommended the seed rate of 180 kg.ha⁻¹ instead.

The interaction effect between the tillage machine and seed density showed no significant difference ($p>0.05$) in the grain yield of the rain-fed wheat and other parameters (Table 2). This result indicates that every understudied factor was independently effective. On the other hand, the mentioned factors (tillage machine and seed density) in this experiment had equal or similar effects on the yield of Tajan rain-fed wheat and yield components.

CONCLUSIONS

The presence of plant residues or stubbles in the second and third years of experiments had positive influence on the weight of 1000 seed and the mean number of seeds in each spike or cluster versus tillage machine treatments.

Tillage implements and seeding rates had no significant effects on the yield of rain-fed wheat. The optimum seed density recommended was between 350 seeds.m⁻² (140 kg. ha⁻¹) and 400 seeds.m⁻² (150 kg.ha⁻¹) to increase the grain yield at reduced production costs. Among the ploughing machines, the chisel plough showed increased yield in comparison with the others.

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