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THE PERFORMANCE OF DEVELOPED ROTARY TILLER FITTED WITH PNEUMATIC SEEDER

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Abstract

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The objective of this study was to evaluate the performance of new developed rotary tiller fitted with pneumatic seeder which can perform tillage and cereal seeding in one pass. The seeding performance of developed machine was examined at laboratory conditions then its performance was compared with conventional seeding machine in the field conditions.

The developed machine performs the seeding by first tilling the soil with rotary tiller then placing the seeds with the help of seeding tubes over which soil is evenly distributed. And finally, the seeds are covered by tilled soil and straw. Developed machine enables the seeding by one pass in the field which will decrease the field traffic and prevent the hazardous effects of buried straw on the seeds. Thus, it provides lower energy inputs, increased work rates and timeliness.

First the seeding uniformity of the developed machine was examined at laboratory conditions and then compared with conventional seeding machine in the field tests for forward speeds at 1, 1.5, and 2 ms^{-1} and slopes of the field at 5%-10% and 15%.

According to the results, developed machine had similar seedling emergence rate with conventional (80 % and 82 %), while allowing reduced tillage for cereal seeding along with fuel saving when compared to conventional seeding system. Fuel consumption of the developed machine was 16.16 Lha^{-1} whereas this was 29.60 Lha^{-1} for conventional seeding system. Developed machine provided better fuel consumption with almost twice less specific power requirement while creating similar seeding conditions as conventional system.

When we compare the developed machine with conventional seeding systems for plant emergence and yield parameters in the field, there was no statistical difference regarding plant emergence, shoots ratios, grain yield, stalk/grain ratio, and number of plants per 1 m^2 area.

Key words: seeding, rotary tiller, minimum tillage, seed placement, emergence, energy

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Introduction

The main objectives in the conservation tillage systems are to till the soil without inverting while maintaining 30% residue cover in the field. Comparing the conventional system, reduced tillage and direct seeding methods are the applications to conserve the soil and to save time and fuel.

In conventional tillage system, intensive tillage increases the risk of erosion. Soil erosion caused by water and wind is a widespread problem in the world. Especially bare soil which is not covered with plants or straw is susceptible to erosion risk. In the year of 1999, 12% of the agricultural fields are exposed to severe erosion in the world (Lal, 2003).

To prevent or lessen the risk of water and wind erosion; the following should be practiced: reducing the impact of the water drop on soil surface, preventing decomposing and dispersion of soil aggregates, increasing infiltration, and reducing surface water flow speed. The longer duration of covering soil surface with plants the more reducing the effect of water and wind erosion risks. Beside this, cover plant reduces the kinetic energy of rain drops (Aykas et al., 2005).

For example; the field covered with 0.57 Mg ha^{-1} straw mulch reduces the erosion 25% comparing the field without mulch (Meyer, 1963). Plant residues prevent soil particles from breaking to rainfall events by absorbing the kinetic energy and as a result of this, soil particles can not be moved easily by water and wind.

Avoiding compaction and decreasing field traffic to get a good soil structure reduce risks of the water and wind erosion in conservation tillage (Onal, 1995). For this reason, conservation tillage and direct seeding are widely used in the world as an alternative to the conventional tillage methods in which soil is inverted (Sommer and Köller, 1989).

Sufficient water, oxygen and a convenient soil temperature should be available in the soil for seed germination (Berkmen, 1961). Light, air, water, heat, and plant nutrition are needed for a good plant growth after germination. To benefit from these elements and to prevent competition among emerging seedlings, it is important to create homogenous spaces between plants. The larger space for the plant allows more benefiting from elements in the soil (Zeltner, 1976). Optimum spacing incorporating previous crop residue in the soil reduces nitrogen loss, enriches organic substance in the soil and increases the water retention capacity (Powlson et al., 1985; Tebruge, 1983).

In this study, a rotary tiller fitted with a soil conveyor and pneumatic seeder was developed for tilling the soil and seeding cereal by one pass. The performance of developed machine was compared with the performance of conventional row seeding machine (Machine B) used widely in Aegean Region, Turkey.

Materials and Methods

The developed "Rotary Tiller Fitted with a Pneumatic Seeder"

The developed rotary tiller fitted with pneumatic seeder was designed and manufactured at Ege University, faculty of agriculture, department of agricultural machinery. The machine consists of rotary tiller on which pneumatic seeding unit mounted, soil lifting plate and soil conveyor (Figure 1). The machine was attached to a tractor's three-point hitch system. The

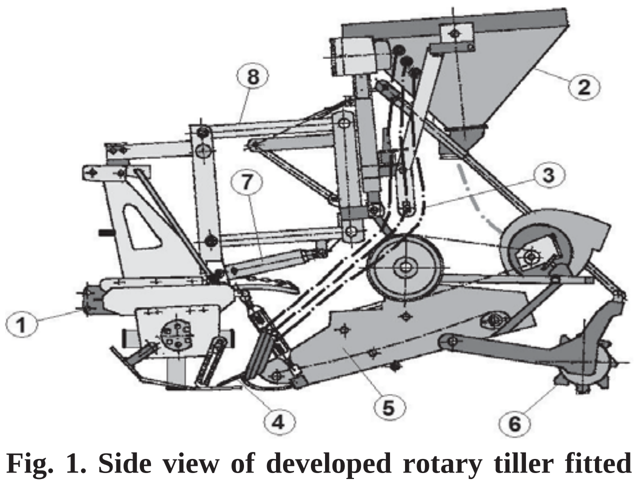

Fig. 1. Side view of developed rotary tiller fitted with a soil conveyor and pneumatic seeder. (1) Rotary tiller; (2) Seed tank; (3) Seeding tubes; (4) Soil plate; (5) Soil conveyor; (6) Toothed rolled; (7) Hydraulic cylinder; (8) Parallelogram frame

pneumatic seeding unit, soil lifting plate, and conveyor were mounted on a rotary tiller's frame. The seeding unit, seeding bar and conveyor were raised and lowered by a hydraulic cylinder.

The soil was first tilled by rotary tiller at 5 cm depth and the tilled soil was thrown over the soil plate on the conveyor which consists of steel bars with 25 mm spacing to allow the soil pass through. The soil plate prevents the mixing of the seeds and soil during seeding. The soil on the conveyor covers the seeds which were placed by seeding tubes underneath of the soil plate during conveyor movement. First, fine soil granules, then the coarse soil granules and residue at the end of the conveyor pass through the bars to cover the seeds (Figure 2). The fine soil granules and coarse soil granules and residue form approximately 1 cm and 4 cm thick soil layers over the seed, respectively. Finally, the soil layer was compressed by press wheel which completes the seeding job.

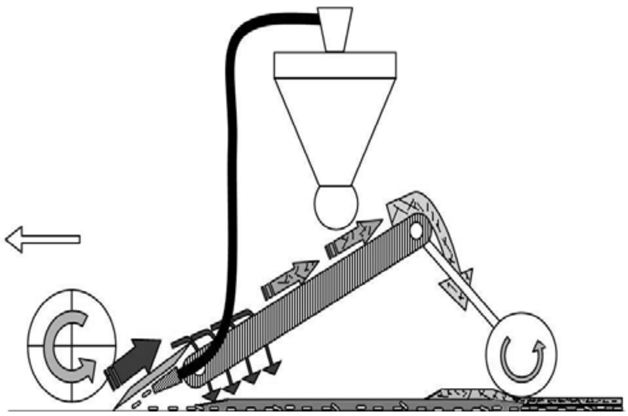

Fig. 2. Schematic diagram of developed machine during working

The ends of the seeding tubes (6 tubes) were formed in a way that it spreads the seed uniformly (Figure 3). The working width of the machine was 1300 mm.

Conventional Row Planting Machine

The conventional row planting machine consists of a fluted wheel seeding unit and disk coulters. The working width of the machine was 2500 mm and the setting angle of the single concave disc was 10°.

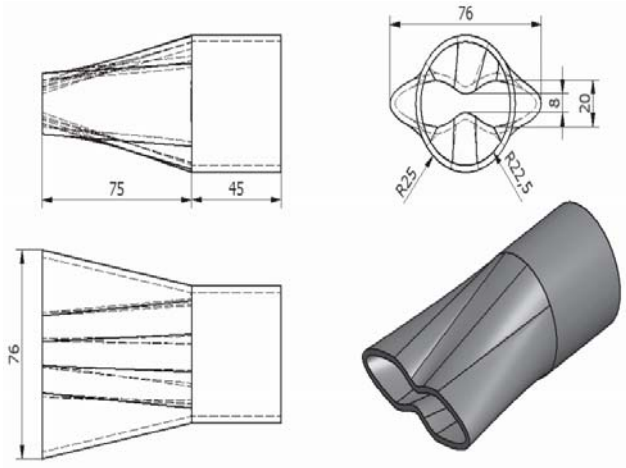

Fig. 3. Seeding tube developed to give uniform seed placement

Seeds

Cumhuriyet 75 (*triticum aestivum*) wheat seed variety was used for seeding in both laboratory and field experiments. This variety is used widely in the Ege region of Turkey and it has a high emergence rate (97%). Thousand seed weight was 39.4 gram.

Laboratory Tests

- Determining Proper Seeding Tube of the Developed Seeder

Before checking the seeding performance of the developed machine, the preliminary laboratory tests were conducted to determine the proper seeding tube of the developed seeder. Different shapes of tubes were examined in zero slopes with 1.5 ms^{-1} forward speed at laboratory conditions. The greased plate was used to determine the optimum air velocity and the shape of seeding tube to get even distribution on the plate. The seed distribution was checked with Chi Square test. The seeding tube with final end bent (Figure 3) and the air speed of 20.8 ms^{-1} were selected for broadcasting the seeds in the row uniformly so that one seed per 50x50 mm^2 (800 seeds in 2 m^2) area is sown for a sufficient life space for one plant (Onal, 1995).

- Determining Performance of Developed Machine at Laboratory Conditions

After preliminary laboratory tests, transverse and area seeding uniformity (Aykas, 1988; Aykas et al., 1990; Mahlstedt, 1972) of the adjusted developed seeder was measured at different working conditions to determine the performance of the machine at laboratory conditions. The machine was tested at four different working positions (0, 5%, 10%, 15% side slopes) and three working speeds (1, 1.5, 2 ms^{-1}) with three replications.

- Determining Area and Transverse seeding uniformity of Developed Machine

Seeding machine was adjusted just to sow 800 seed in 2 m^2 area by changing the length of the flutted roller of the seeders. With this adjustment, the seeding rate was 15.76 kg da^{-1} (since the thousand seed weight was 39.4 gram and expected number of seed is one for each 50x50 mm^2 area).

Transverse Seeding Uniformity

The greased plate with 1 m wide and 4 m long on which lubricating grease was spread was used to determine area and transverse seeding uniformity. Leaving 1 m gap from beginning and at the end, the middle of the plate was divided by 50x50 mm^2 areas so that the seeding area for each seed was formed. The total seeds in one column for 2 m length and 50 mm width were expected to be 40 seeds (1 seed for each 50x50 mm^2 area in 40 rows). The total seeds were counted in each column, and the transverse seed distribution uniformity was calculated from the average of the total number of seeds counted from each column in 1 m width. The total number of seeds expected was 800 (20 columns x 40 rows). ANOVA Statistical analysis was made to examine the transverse seeding uniformity of the developed machine.

Area Seeding Uniformity

The area seeding uniformity of the developed machine was checked with the Chi Square tests. For this purpose, the seeds were counted in each 50x50 mm^2 area in 2 m length and 1 m width seeding area. The area seeding uniformity of seeding was tested for Poisson distribution by chi square tests (Mahlstedt, 1972). To calculate the Chi Square and m values, following equations were used.

$$\chi^2 = \frac{\sum(\chi_i - Mj)^2}{Mj} \qquad (1)$$

Where: ci = Observed data in each 50x50 mm^2 area

Mj= Expected data

The expected data was calculated as,

$$Mj = \frac{\mu^r}{r!} \cdot e^{-\mu} \qquad (2)$$

Where: r = Number of seeds

m= Poisson population average

e =Natural logarithm value

and m value was calculated from;

Where: l: Total seed number counted in the area

q: Theoretical cell number that should be in the area

$$\mu = \frac{l}{q} \qquad (3)$$

The calculated Poisson population average (m) is expected to be 1 for the best distribution in which only one seed are observed in each 50x50 mm^2. The best area distribution implies the lowest calculated chi square value comparing table chi square value and Poisson population average (m) value of close to 1.

Field Tests

The field experiment was conducted in dry soil conditions in the experiment field of Ege University, Faculty of Agriculture, Bornova, Izmir, Turkey. The prevailing climate is Mediterranean with a long-term mean annual temperature of 16.8 °C. Long-term mean annual precipitation is 542.3 mm, about 75% of which falls during the winter and spring, and relative humidity is 57.1%.

The Experimental soil was characterized by sandy loam texture (14.4% clay, 25.28% silt, and 60.32% sand) with slightly alkaline reaction and classified as a Typic Xerofluvent (Soil Survey Division Staff, 2006).

For preparation of the field for planting for conventional system, the field was ploughed with a moldboard plough and disk harrowed two times and finally it was leveled with float for preparing the seedbed for planting at 5 cm depth. The field was not tilled for developed machine. For developed machine, seeding was made directly in the field covered 30% wheat residue after collecting stalks from the field. Planting was made in dry soil conditions for both machines. Short after the planting, enough moisture was obtained in the field by autumn rains.

The field studies of the machines were conducted in a randomized-block design (four blocks) with four replications, in 2003. Sowing was made in October 10, 2003. The plot dimensions were 3 m wide and 50 m long.

In the field tests, number of plants in 1 m^2 area, seedling emergence, shoots ratio, stalk grain ratio and yield of developed machine and conventional seeding system were measured.

Determining Performance of Seeding Machines in the Field

To determine the performance of the seeders in the filed tests; working characteristics of the machines were examined. Slip, specific power requirement, fuel consumptions at flat surface were calculated from the measured speed, draft force, and torque to determine the working characteristic of the machines, and its effects on the yield were determined. The working speed was selected as 2 ms^{-1}.

The draft requirements of the machines were measured by load cells mounted on the three-point hitch of the tractor. The signals received from the load cells were amplified by an amplifier Adam 5000 before being sent to the computer to be saved (Figure 4).

The power requirements and fuel consumptions of the machines were measured using a torque-meter mounted on the PTO shaft and fuel meter mounted on the fuel system of the tractor, respectively. Specific power requirement of the machine was calculated from the measured torque for rotary tiller and draft force of the seeders and speed of the machine as follows,

$$P_{draft} = \frac{F.V}{b} \qquad P_{torque} = \frac{T.n}{b.60} \tag{4}$$

P = specific power (kWm^{-1})
F = draft force of the machine (kN)

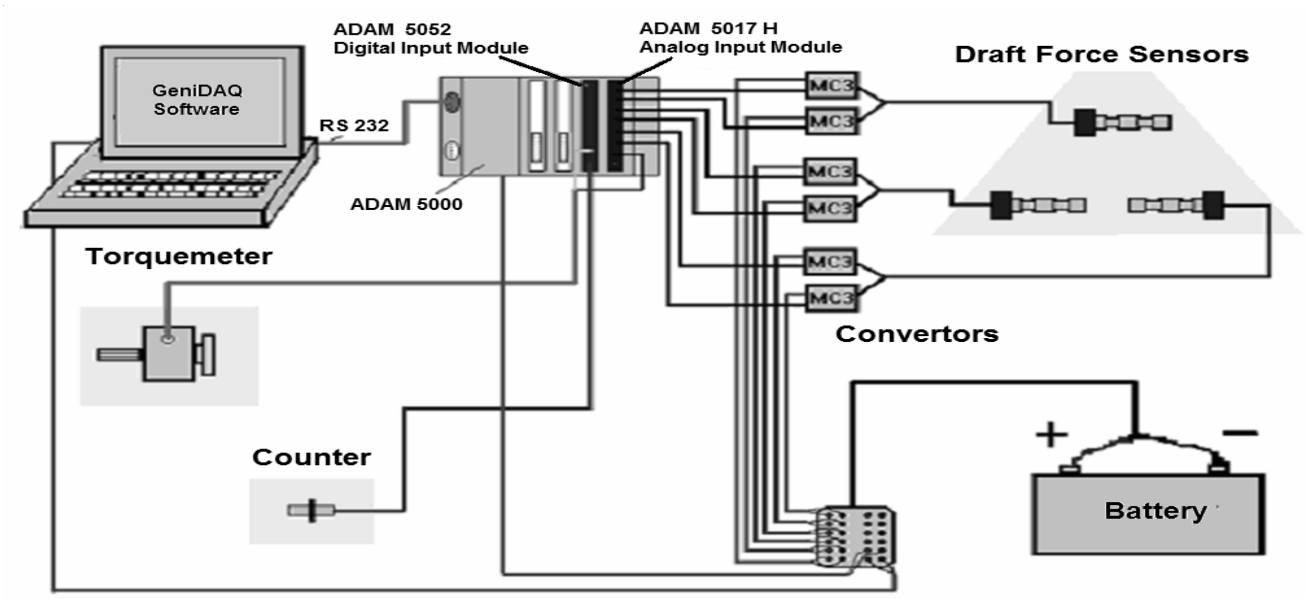

Fig. 4. The measurement set for determining the working parameters of the machines

T = torque of the machine (kNm)
V = working speed (ms^{-1})
n = number of revolutions of the PTO (min^{-1})
b = working width of the machine (m)

ANOVA Statistical analysis was made to examine difference of seeding performance between the seeders by checking the Duncan's test and LSD values for *P<0.05 level of statistical significance.

- Determining Seedling Emergence Rate of Seeders in the Field

Emerged seedlings were counted in randomly selected 3 m^2 area after 10, 15, and 20 days of planting in the field for determining seedling emergence rate of seeders.

- Determining Area and Transverse Plant Uniformity of Developed Machine in the Field

Area and transverse plant uniformity of the developed machine in the field were measured in a similar way used in the laboratory. A wooden frame (3x1 m^2) which was divided into 50x50 mm^2 areas by tight rope was used to determine the planting uniformity in the field. The wooden frame was randomly placed in the field to count the emerged seedlings.

Results and Discussion

Results of Laboratory Experiments

- Seeding Uniformity of Developed Machine at Laboratory Conditions

The number of seeds sowed per area with the developed machine in different slopes and working speeds were given in Table 1. It was found that slope and working speed affects only transverse seeding uniformity of the developed machine statistically. Increased speed caused excessive planting seed number and this effect increased with increasing the slope of the machine. The m values were found close to one for all slopes and speeds of the developed machine for area seeding uniformity meaning that speed and slope had no effect on the area seeding uniformity (Table 2). But Chi square values were found to be high in working speeds of 1 and 1.5 ms^{-1}.

Table 1

Statistical analysis of transverse uniformity of the developed machine at laboratory conditions

Slope, %	Forward speed, ms^{-1}	Average seed number per 2 m row length
Flat	1.0	40.5[a]
	1.5	42.3[b]
	2.0	48.5[c]
LSD		1.5
5% Slope	1.0	41.2[a]
	1.5	48.3[c]
	2.0	46.0[b]
LSD		1.7
10% Slope	1.0	42.7[a]
	1.5	45.6[b]
	2.0	48.6[c]
LSD		1.9
15% Slope	1.0	41.3[a]
	1.5	45.2[b]
	2.0	44.6[b]
LSD		1.8

Table 2
Statistical analysis of area uniformity of the developed machine at laboratory conditions

Slope, %	Forward speed, ms^{-1}	η	$\aleph^2$ value	Table value
	1.0	1.08 [a]	38.07	11.7
Flat	1.5	1.06 [a]	7.90*	1.9
	2.0	1.21 [a]	4.95*	11.7
	1.0	1.03 [a]	10.4	1.9
	1.5	1.21 [a]	8.28*	1.9
5% Slope	2.0	1.15 [a]	1.11	1.9
	1.0	1.07 [a]	9.79*	11.7
	1.5	1.14 [a]	4.44*	11.7
10% Slope	2.0	1.21 [a]	3.48*	1.9
	1.0	1.03 [a]	1.10	1.9
15% Slope	1.5	1.13 [a]	7.60*	1.9
	2.0	1.12 [a]	6.64*	1.9

* $\aleph^2$ values below the table value.

Results of Field Experiments

- **Soil Moisture**

Soil moisture was measured after 20 days from seeding (Figure 5). Soil moisture was found low at soil surface (0-5 cm) as 18% and 14.6% for developed machine and conventional system respectively. According to the statistical t-test results, soil moisture difference was found significant at 0-5 cm depth. This is because of layered soil with fine granules covered with coarse soil granules including residues on top of the soil which kept the moisture in the soil for developed machine. Soil moistures were high in soil depths of 10 to 15 cm as 21.8% and 21.2% for developed machine and conventional system, respectively comparing the soil surface.

- **Bulk Density of the Soil**

Bulk densities of the soil were measured after seedling emergence (Figure 6). Although there was found no significant difference, bulk densities were found higher in developed machine comparing to the conventional machine especially at 0-5 cm depth according to the statistical analysis. For other depths, 5-10 cm and 10-15 cm, bulk densities were similar for both systems.

- **The Seedling Emergence and Shoots Rates of Seeding Systems**

The seedling emergence rates of the developed machine and conventional seeding systems were given in Figure 7. According to the results, average seedling emergence rates were found to be 80 % and 82 % for developed machine and conventional seeding system, respectively. It was found no statistical differ-

Table 3
Statistical analysis of yield parameters of the seeding systems

	Average number of plants in 1 m^2	Average stalk-grain ratio	Average yield, Mg ha^{-1}
Developed machine	328 [a]	1.095 [a]	3.27 [a]
Conventional System	335 [a]	1.09 [a]	3.21 [a]
LSD	44.46	0.06	0.29

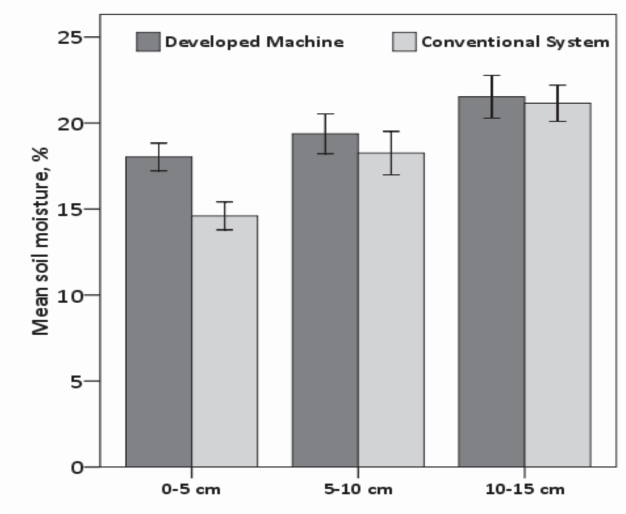

Fig. 5. Mean soil moistures of the soil after seedling emergence in the field experiments

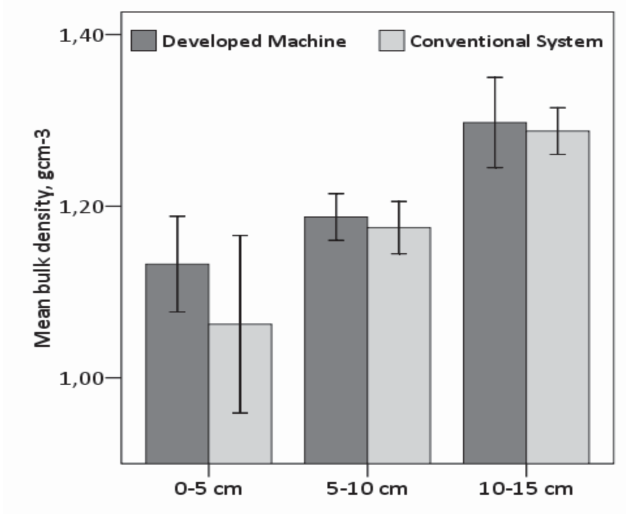

Fig. 6. Mean bulk densities of the soil after seedling emergence in the field experiments

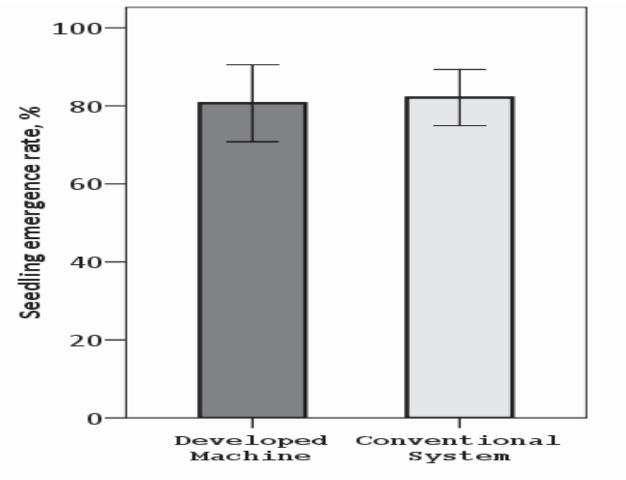

Fig. 7. Seedling emergence rates of the wheat plant in the field experiments

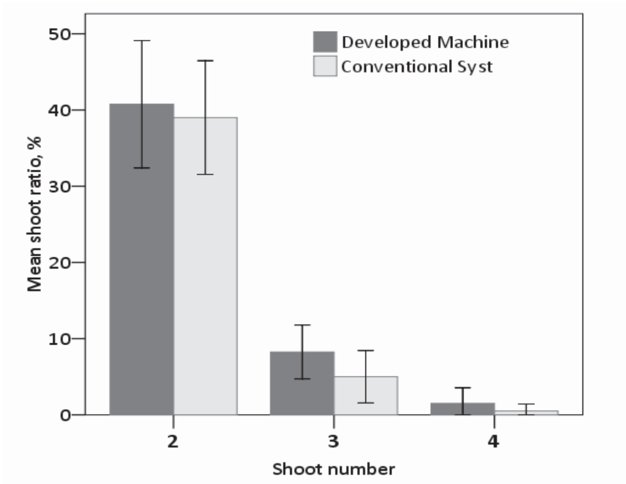

Fig. 8. Mean shoot ratios of wheat plants in the field experiments

ence regarding seedling emergence.

The shoots ratios were found to be similar for both planting systems and the difference were not statistically significant (Figure 8).

- Yield Parameters of Seeding Systems

The number of plants per 1 m^2 area, stalk grain ratio, and grain yield were measured as plant yield parameters. Yield parameters were given in Table 3. According to the statistical analysis, there was no significant difference between seeding systems for average grain yield, stalk/grain ratio, and number of plants per 1 m^2 area in the field experiments. The average yields were calculated as 3.27 Mg ha^{-1} and 3.21 Mg ha^{-1} for developed machine and conventional seeding system, respectively

- Working Characteristics of Planting Systems

Specific power requirement, slip and fuel consumption were taken as working characteristics of the machines for both systems. Results and statistical analysis are given in Table 4. Fuel consumptions were measured 16.16 Lha^{-1} for developed machine and 29.60 Lha^{-1} for conventional system. According to the

Table 4
Statistical analysis of working characteristics of the seeding systems

	Slip, %	Specific power, kWm^{-1}	Fuel consum., $L\ ha^{-1}$
Developed machine	8.30^{a}	11.66^{a}	16.16^{a}
Conventional System	6.10^{b}	33.47^{b}	29.60^{b}
LSD	0.54	2.8	2.1

results, developed machine provides better fuel consumptions with almost twice less specific power requirement while creating similar seeding conditions with conventional system.

Conclusions

In this study, rotary tiller fitted with a soil conveyor and pneumatic seeder was developed to perform tillage and cereal seeding in one pass. The developed seeding machine was compared with conventional seeding systems to examine its seeding performance. According to the observations made through laboratory and field experiments, generally, it can be said that the developed machine performed seeding well comparing the conventional system with less time and fuel consumption.

According to the results, developed machine had similar seedling emergence rate with conventional (80 % and 82 %), while allowing reduced tillage for cereal seeding along with fuel saving when compared to conventional seeding system. Fuel consumption of the developed machine was 16.16 Lha^{-1} whereas this was 29.60 Lha^{-1} for conventional seeding system. Developed machine provided better fuel consumption with almost twice less specific power requirement while creating similar seeding conditions as conventional system.

Beside the fuel saved, minimum soil disturbance and minimum field traffic (due to preparing seed bed in one pass), the developed machine was able to conserve the soil moisture especially in the 0-5 cm soil depth with the help of aggregate layering and residue covering.

When we compare the developed machine with conventional seeding systems for plant emergence and yield parameters in the field, there was no statistical difference regarding plant emergence, shoots ratios, grain yield, stalk/grain ratio, and number of plants per 1 m^2 area.

This developed rotary tiller fitted with a pneumatic seeder will not only perform seeding with lower costs but will also allow better soil conditions for plants to develop comparing conventional seeding system.

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