Indian Journal of Ecology (2022) 49 Special Issue (18): 18-23

Manuscript Number: S-768
NAAS Rating: 5.79

Effect of Tillage Depths and Static Magnetic Seed Treatment on Growth Parameters and Yield of Maize (*Zea mays* L.)

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Abstract: A field experiment has conducted during the autumn growing season of 2019 in one of the agricultural fields affiliated in the district of Amarah-Maysan province center, south of Iraq. The aimed research is to study the effect of tillage depths and the exposure of maize seeds to static magnetic fields, and their combinations on growth parameters and yield of maize (*Zea mays* L.) cultivar Bohooth 106. Randomized complete block design with a split-plot design was used with three replications. The main plots included three levels of plow depths, 20cm (TD1), 25cm (TD2), and 30 cm (TD3), while the sub-plots include seeds that have subjected to a static magnetic field of 125 mT for three different times 0 hr (control, Mg1), 3hr (MG2) and 6hr (MG3). The results showed that tillage depths TD3 and magnetically treated seeds MG3 significantly affected all growths and yield parameters of a maize plant under study. The interaction treatments TD×MG was significantly superior for all growth and yield parameters. The interaction TD3×MG3 gave the maximum plant height (167.30 cm), leaf area (370.33 cm2), stem diameter (172.80 mm), the number of grains ear^{-1} (294 grain), 500-grain weight (205.40 gm), and grain yield (6.04 ton. ha^{-1}). The best results yield can be obtained at tillage depth 30 cm and magnetic time exposure 6 hours in all growths and yield parameters.

***Keywords*:** Static agnetic field, Tillage depth, Maize yield, Growth parameters

Maize (*Zea mays* L.) is known as an important seasonal cereal crop relating to family Poaceae (Solieman et al 2019) and is considered one of the most important food crops in several parts of the world, both as a staple food for humans and as animal feed (Tandzi and Mutengwa 2020). Tillage practices are one of the most important for higher maize crop production, which modifies soil physical properties such as soil moisture content, soil bulk density and resistance to soil penetration (Bramdeo and Ratony 2020, Tandzi and Mutengwa 2020). Tillage has primarily been undertaken to mix the soil with the residues and fertilizer, which in turn leads to enhances root growth germination and development crop yield production (Sharma et al 2018). Moreover, the tillage system has some suitable properties, such as breaking crusts and preparing a suitable seedbed according to the area's soil type and environment (Ozpinar and Ozpinar 2015). Hence, these changes lead to preparing a suitable seedbed for germination (Shah et al 2014). Tillage practices can increase the water movement in the soil and enhances root distribution growth (Khurshid et al 2006). The improvement effects of tillage on some growth parameters of maize seeds plant height and leaf area (Otieno et al 2020, Solieman et al. 2019), stem diameter (Zaidan et al 2019), the number of grains per ear and an average weight of 1000 grains (Khurshid et al 2006) and in the total yield of grain is well documented (Bramdeo and Ratony 2020 and Otieno et al 2020). On the other hand, the use of magnetic treatment procedures is considered one of the most effective methods for improving plant growth and plant production, and this is due to its less harmful environmental effects (Nyakane et al 2019). A magnetic field (MF) has usually found in a static or alternating mode. The static magnetic field (SMF) comes either from a static magnet as a magnetic medium or from the direct current fed electromagnets. The alternating magnetic fields are a time-varying electromagnetic that comes from the alternating current movement. The magnetically treated seed germination depends on its magnitude and its nature, static or alternating. In general, the SMF effects process of growing plants has depended on the magnetic exposure dose, i.e., the output of the magnetic field flux density and the exposure time (Pietruszewski and Martinez 2015). Previous studies reviewed the beneficial effects observed in a magnetically treated seed for different cereal crops, which depend on the particular magnetic treatment applied, such as exposure time and magnetic field power, stationary or alternating. The positive growth response to the static magnetic field varying between 50 and 250mT at different exposure of time-varying in maize seeds is observed by Vashisth and Joshi (2017) and Torres et al (2019). A similar positive response was obtained in wheat seeds (Lazim and Ramadhan 2019, 2020) in cereal (Martinez et al 2017, in sorghum seed (Lazim and Nasur 2017), in pea and lentil seeds (Martínez et al 2009) and in barley seed (Martinez et al 2000). There are no studies on the impact of tillage systems in combination with magnetic treatments on output maize growth assessment. This study, therefore, aimed to project to determine some growths and yield parameters of maize seeds (*Zea mays* L.) exposed to magnetic fields under different conditions of tillage depths.

MATERIAL AND METHODS

During the autumn season 2019, the field experiment was conducted in Amarah-Maysan province center district (southern Iraq).

Physio-chemical properties of soil of experimental site: Soil samples were taken randomly from different places of a plot at a depth of 0-30 cm and were air-dried, crushed by hand, and sieved through a sieve with a 2mm opening. Soil samples were at University of Basrah, for record some physical and chemical properties using standard methods and procedures (Table 1).

Table 1. Soil physicochemical properties that used in the experiment

Determination	Units	Values
Soil pH	-	7.8
Electrical conductivity (ECe)	dSm^{-1}	2.3
Cation exchange capacity (CEC)	$Cmol.Kg^{-1}$ Soil	7.40
Organic matter (O.M0	g.Kg-1	12.4
Positive soluble ions		
Calcium (Ca++)	$mmol.L^{-1}$	1.85
Magnesium (Mg++)	$mmol.L^{-1}$	0.16
Potassium (K+)	$mmol.L^{-1}$	-
Sodium (Na+2)	$mmol.L^{-1}$	8.55
Negative soluble ions		
HCO3-	$mmol.L^{-1}$	0.2
SO4-2	$mmol.L^{-1}$	2.69
CL-	$mmol.L^{-1}$	4.82
Elements		
Nitrogen (N)	$mg.Kg^{-1}$	25
Phosphorus (P)	$mg.Kg^{-1}$	10.12
Potassium (K)	$mg.Kg^{-1}$	16.24
Soil characteristics		
Sand	$gm.Kg^{-1}$	73
Silt	$gm.Kg^{-1}$	569
Clay	$gm.Kg^{-1}$	239
Soil texture		Loamy clay
Bulk density	$gm.cm^{-3}$	1.19
Porosity	-	55%

Experimental design and treatments: The experiment has carried out with three replications and nine treatments in randomized complete block design, where the treatments are combinations of tillage depths and magnetized seeds. Each experimental plot are, was 2 × 3 m. Each plot consisted of three plant lines, the distance between lines was 60cm, and plant distance was 25cm far. The number of plants per plot 30 plants, plant density per hectare comes to 50000. The disc plow was used for plowing the soil before sowing. The soil texture was loamy clay as ell (Table 1).

The crop was kept free from weed, insects pests and diseases. Watering, hoeing, and weeding was carried out whenever needed. Seeds of maize were exposed to a static magnetic field of 125 mT in a cylindrical plastic sample holder for ranging 0-6 h durations in steps of 3 h, 0h as non-exposed seeds (control). The magnetically treated seeds have planted every four seeds in the hole.

Fertilizer application: Nitrogen fertilizer in form of urea (46% N) at a rate of 200 kg. ha^{-1} was added in twice batches. The first rate of 100 $kg.ha^{-1}$ was applied at the time of planting and the second after one month of seeding. Potassium fertilizer form of potassium sulphate K_2SO_4 (44% K) at a rate of 100 kg. ha^{-1} was added before planting.

Data collected: The height of the plant, the leaf area and stem diameter were measured at the flowering stage. However, the number of seeds, the weight of 500-grains, and the final yield have been reported at harvest time.

Statistical analysis: The statistical analyses were used in the experiment study, according to randomized complete block design, by split-plot arrangement. Three tillage depth levels have been included in the main plots, while three seed pretreatment levels with a static magnetic field have been included in the subplots. The analyses have been done with SPSS.

RESULTS AND DISCUSSION

Plant height: Plant height was affected significantly by tillage depths (Table 2). The maximum plant height (161.21 cm) was in tillage depth 30 cm, which increased significantly by 3.94 and 4.47 as compared to tillage depths 20 and 25cm, respectively. This observation might agree with those findings by several researchers, who reported that the height of the maize plant was affected significantly during the application of various levels of the tillage depth system (Solieman et al 2019, Otieno et al 2020). Tillage practices change soil structure by modifying its physical properties such as soil moisture content, the density of soil bulk, and resistance to soil penetrations (Rashidi and Keshavarzpour 2007). Higher plant height with increased tillage could be due to decreased soil bulk density, which enhanced root proliferation for nutrient uptake as well as humidity (Wasaya et al 2012, Khan et al 2017, Anjum et al 2019, Wang et al 2019) and Moreover, higher plant height in tillage treatment (30 cm) might be due to better physical conditions of uniform distribution of soil nutrients and higher porosity (Anjum et al 2019). Based on magnetic seeds treatment, the maize plant height was affected significantly by various levels of exposure times (Table 2).

Comparing the magnetic-treated seeds, the highest of plant height was 160.30cm in magnetically treated seeds of 6 hours with a significant positive effect, which increased by 3.86% and 2.89% compared to untreated (154.11cm) and 3 hours treatment (155.66), respectively. These findings might be parallel to the results of the previous authors, who found an increase in the height plant as positive to various SMFs for different exposure times in maize and other crops. For example, Florez et al (2007) found that maize seed exposed to a magnetic of 125 or 250 mT for different periods stimulated the total length (stem + root) under laboratory conditions. Similar results were shown by Vashisth and Joshi 2017) also concluded that shoot and root growth of maize seeds has increased with static magnetic fields of strength 200 mT for 1 hr. Also, Alzubaidy (2014) reported an increase in plant height of maize by three different values of magnetic fields, 100, 200, and 300 mT. Moreover, under the magnetized water treatments, an increase in plants height was found on maize by Taj– Al deen et al (2009). The higher maize plant height in MG3 treatment seeds may be linked to the stimulation of phytohormones such as auxin, cytokinin, and gibberellin (Siyami et al 2018). The data indicate a significant impact on plant height of the interaction between depths tillage and the treatment of magnetic seeds. The highest values of plant height have been recorded in the combination treatment of TD3×MG3 167.30 cm and TD3×MG2 160cm.

Plant leaf area: The leaf area was affected significantly by various levels of depth (Table 3). The highest value of the leaf area was 336.33 cm^2 from depth TD3, while the lowest leaf area of 250.16 cm^2 was recorded from minimum depth TD1. Leaf area has been enhanced up to 25.62% by depth TD3 as compared to minimum tillage TD1.

The agreed with those findings of earlier reserchers (Aikins et al 2012, Khan et al 2017, Zaidan et al 2019) under different tillage systems. The maize leaf area is necessary for photosynthesis and yield, where the leaf area is of importance to the detection of light radiation and thus has a significant impact on crop yield (Aikins et al 2012). As relates to magnetic treatment, data concerning the leaf area of maize (Table 3) have shown significant influence of magnetic exposure times in the leaf area of maize. The highest value of the leaf area 302.60 cm^2 was from exposure time MG3, while the lowest leaf area of 262.87 cm^2 has been rcorded from untreated seeds MG1. Leaf area has been enhanced up to 13.16% by MG3 as compared to MG1. Shine and Guruprasad (2012) reported that higher magnetic treated levels influence the leaf area of maize. Anand et al (2012) reported decreased levels in antioxidant defense system enzymes in leaves maize leading to enhanced leaf water status and photosynthesis rate. These findings indicate that maize seed pre-sowing magnetic treatment can increase the leaf area of maize plant (Shine and Guruprasad, 2012Thehighest values of plant height have been recorded in the combination treatment of TD3×MG3 (370.33cm2) and TD3×MG2 (354cm^2).

Diameter of stem: Table 4 indicates that tillage depths and magnetic seed treatments caused a significant effect on the stem diameter. Tillage TD3 caused a high stem diameter of 166.82 mm significantly compared to the depths TD1(153.60mm) and (TD2 157.11mm), which increased by 7.92% and 5.82%, respectively (Table 3). These results might be similar to those findings by several researchers, who found that the stem diameter of the maize plant was affected significantly during the application of various levels of the

Table 2. Effect of different exposure times magnetic field and tillage depths on the maize height (cm)

Tillage depth (cm)	SMF exposure time (hour)			
	MG1	MG2	MG3	Mean
TD1	152.33^{b}	153.47^{b}	158.77^{b}	154.86^{b}
TD2	153.67^{b}	153.50^{b}	154.83^{b}	154.00^{b}
TD3	156.33^{b}	160.00^{ab}	167.30^{a}	161.21^{a}
Mean	154.11^{b}	155.66^{b}	160.30^{a}	
L.S.D (p=0.05)	Interaction= 7.77 Tillage depths = 5.72, Magnetic=3.51			

Different superscript letters across each column are mean significantly different at P< 0.05 level

Table 3. Effect of different exposure times magnetic field and tillage depths on the leaf area of maize (cm^2)

Tillage depth (cm)	SMF exposure time (hour)			
	MG1	MG2	MG3	Mean
TD1	233.67^{b}	247.00^{b}	269.80^{b}	250.16^{b}
TD2	270.00^{b}	265.33^{b}	267.67^{b}	267.67^{b}
TD3	284.76^{b}	354.00^{a}	370.33^{a}	336.33^{a}
Mean	262.78^{b}	288.78^{a}	302.60^{a}	
L.S.D (p=0.05)	Interaction= 51.58 Tillage depths = 37.94, Magnetic= 24.42			

Different superscript letters across each column are mean significantly different at P< 0.05 level tillage depth system (Zaidan et al 2019, Lawrence et al 2020). Stem diameter has a vital role in grain yield and plant biomass of maize crop under field conditions (Anjum et al 2019). The stem diameter of maize (Table 4) have shown that significant influence in magnetic exposure times. The highest value of the stem diameter 162.20 mm was obtained from exposure time MG3, while the lowest stem diameter (155.67 mm) from untreated seeds MG1. Stem diameter has been enhanced up to 4.02% by MG3 as compared to MG1.

Flores et al (2007) reported an increase in the stem growth of maize plants from the treatment of maize seeds in a static magnetic field of magnetic strengths 250 mT. Zepeda-Bautista et al (2014), indicate that the stem diameter of corn plant was significantly affected with 12 min exposure to electromagnetic field treatment by 3.19%, compared to the non-irradiated control. During the germination of maize seeds, the static magnetic field probably produces biological and biochemical changes in cell structures by stimulating the activity of proteins and enzymes, leading to an increase in seed growth potential (Martinez et al 2017). The highest values of stem diameter have been recorded in the combination treatment of TD3×MG3 172.80mm and TD3×MG2 169 mm.

Number of grains ear^{-1}: Tillage depths and magnetic seed treatments caused a significant effect on the number of grains plant^{-1} (Table 5). In TD3 the number of grains were 267.67 and significantly higher than in depths TD1 254.89 and TD2 252.33, which increased by 4.77% and 5.73%, respectively.

These results might be agreement with those obtained by (Anjum et al 2019, Khurshid et al 2006). As relates to magnetic treatment, data concerning the number of grains of maize (Table 5) have shown that a significant influence in magnetic exposure times in the number of grains of maize. The highest value of the number of grains 281.33 has been obtained from exposure time MG3, while the lowest number of grains 237.33 has been recorded from untreated seeds MG1. Number of grains have been enhanced up to 15.64% by MG3 as compared to MG1. Some researchers had suggested the mechanism of magnetically treated seeds on growing seedlings, including various possible hypotheses. Those hypotheses may be linked to the activities of some enzymes and protein synthesis from magnetically treatment seeds, resulting in increased germination and seedling growth (Martinez et al 2017, Kataria et al 2015). On the other hand, the highest values of anumber of grains have been recorded in the combination treatment of TD3×MT3 (294).

500-grain weight: The weight of 500 grains were affected significantly by various levels of depth. The highest value of the weight of 500 grains (176.70 gm) was obtained from depth TD3, while the lowest weight of 500 grains 148.59 gm were recorded from minimum depth TD1 (Table 6). Weight of 500 grains enhanced up to 15.90% by depth TD3 as compared to minimum tillage TD1. Anjum et al (2019) and Asenso et al (2018) also observed the same trend. Tillage practices affect soil physical, chemical, and biological characteristics, which, in turn, can alter plant yield and growth (Rashidi and Keshavarzpour, 2007). The highest of 500 grains (182.21 gm) was obtained from exposure time MG3, while the lowest number of grains (144.27 gm) from untreated seeds MG1. Number of grains have been enhanced up to 20.82% by MG3 as compared to MG1. The maize plant from magnetically exposed seeds showed enhanced in the growth parameters and yield components of maize, which is consistent with Vashisth and Joshi (2017). Interaction between MG×TD indicted that MG3×TD3 treatment has the highest 205.40 gm 500-grain weight, and the MG1×TD1 treatment has the lowest value 500-grain weight 133.40 gm, and the differences were significant.

Grain yield: The grain yield was affected significantly by tillage depths. The highest grain yield (4.77 ton.ha^{-1}) was recorded from depth tillage 30cm, which increased

Table 5. Effect of different exposure times magnetic field and tillage depths on the maize number of grains

Tillage depth (cm)	SMF exposure time (hour)			
	MG1	MG2	MG3	Mean
TD1	152.00^{d}	153.67^{cd}	155.13^{c}	153.60^{b}
TD2	156.33^{c}	156.33^{c}	158.67^{bc}	157.11^{b}
TD3	158.67^{c}	169.00^{a}	172.80^{a}	166.82^{a}
Mean	155.67^{b}	159.67^{b}	162.20^{a}	
L.S.D (p=0.05)	Interaction= 5.51 Tillage depths = 4.05, Magnetic= 4.07			

Different superscript letters across each column are mean significantly different at P< 0.05 level

Table 6. Effect of different exposure times magnetic field and tillage depths on the weight of 500 grains of maize plant (gm)

Tillage depth (cm)	SMF exposure time (hour)			
	MG1	MG2	MG3	Mean
TD1	133.40^{g}	143.65^{f}	168.73^{c}	148.59^{c}
TD2	145.00^{f}	162.20^{d}	178.50^{b}	161.90^{b}
TD3	154.40^{e}	170.30^{c}	205.40^{a}	176.70^{a}
Mean	144.27^{c}	158.72^{b}	184.21^{a}	
L.S.D (p=0.05)	Interaction= 4.48 Tillage depths = 3.29, Magnetic= 1.63			

Different superscript letters across each column are mean significantly different at P< 0.05 level

Table 7. Effect of different exposure times magnetic field and tillage depths on the grain yield of maize plant (ton.ha^{-1})

Tillage depth (cm)	SMF exposure time (hour)			
	MG1	MG2	MG3	Mean
TD1	3.07^{b}	3.66^{b}	4.72^{a}	3.82^{a}
TD2	3.48^{b}	4.01^{b}	4.82^{a}	4.10^{a}
TD3	3.74^{b}	4.55^{ab}	6.04^{a}	4.77^{a}
Mean	3.43^{b}	4.07^{b}	5.19^{a}	
L.S.D (p=0.05)	Interaction= 1.78 Tillage depths = 1.31 Magnetic= 1.03			

Different superscript letters across each column are mean significantly different at P< 0.05 level

significantly by 3.94% as compared to tillage depths 20 cm. Tillage practices are sensitive to soil physical properties such as bulk density, resistance to penetration, soil water content, soil temperature, and these factors have significant effects on plant production, subsequent plant growth, and yield (Ozpinar and Ozpinar 2015). These results are in line with the findings of several researchers, where the grain yield of the maize plant was affected significantly during the application of various levels of the tillage depth system (Khan et al 2017, Bramdeo and Ratony 2020). In 30 cm deep higher leaf area may have led to higher grain yield as compared to the lower tillage depth. Moreover, the possible reason for the higher grain yield in TD3 depth might be lower soil bulk density, which enhances it to root penetration and nutrient uptake, resulting in higher grain yields (Asenso et al 2018). The magnetic treatment have shown significant influence in magnetic exposure times in the grain yield of maize. The highest value of the grain yield 5.19 ton.ha^{-1} was obtained from exposure time MG3, while the lowest grain yield of 3.43 ton.ha^{-1} from untreated seeds MG1. Grain yield was enhanced up to 33.91% by MG3 as compared to MG1.

Many scientists have observed the positive impact on plant growth and yield crops using magnetic field exposure in maize (Vashisth and Joshi 2017), wheat (Pietruszewski and Kania 2010), and soybean (Baghel et al 2018 and tomato seeds (De Souza et al 2005) The increased amylase and protease activities in corn plants from SMF-pretreated seeds may be responsible for improved maize yields (Kataria et al 2015). Baghel et al (2018) observed increased nitrate reductase activity in plants that appeared from SMF-pretreated seeds, leading to improved soybean yields. The maximum yield was in the combination treatment TD3×MT3 (6.04 ton. ha^{-1}).

CONCLUSION

The tillage depths and magnetic treatments have influenced all of the growth and yield parameters of a maize plant studied. Compared to other treatments, especially in the tillage depth of 30 cm and magnetic exposure time at 6 hours were more suitable treatment to boost growth and yield parameters.

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Received 04 August, 2021; Accepted 04 January, 2022