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RESEARCH ARTICLE

EFFECT OF FINE SOIL PARTICLES, TILLAGE SYSTEMS AND POLYACRYLAMIDE ON WHEAT PRODUCTION AND SOME SOIL CHEMICAL PROPERTIES IN ARID REGIONS

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ABSTRACT

A field experiment was carried out at the Agriculture Research Station of King Abdulaziz University to study the effects of fine soil particles, tillage system and polyacrylamide on wheat production and some soil chemical properties. The design of the experiment was a split-split plot with four replications. The main plot included two soils A and B, (A with 25.2 % silt+ clay while B with 38.5 % silt+ clay). Sub plot included three tillage systems namely: No-tillage (NT), Moldboard ploughing with rotor tiller (CT1) and Chisel ploughing with disk harrow (CT2). The sub-sub plot included three polyacrylamide (PAM) rates and were 0, 10 and 20 kg/ha. The obtained results indicated that soil of location B was better than the soil A because wheat production in location B was significantly higher than that of location A. CT2 produced the highest grain yield for wheat crop followed by NT and CT1 tillage systems respectively. Application of different rates of PAM (10 and 20 kg/ha) increased yield production compared with 0 kg/ha. Soil nutrients including N, P and K were significantly increased in the soil of location B compared to location A. The nutrients also increased by increasing PAM rates in both locations.

INTRODUCTION

Non-toxic, anionic polyacrylamide (PAM) is considered as an effective soil conditioner in the last couple of decades (Sojka *et al.,* 2006). It has been known to improve soil aggregate stability (Agassi and Ben-Hur 1992), improve infiltration rate and soil water retention (Flanagan *et al.,* 2003), reduce runoff (Letey, 1996) and soil erosion (Sojka *et al.,* 2007). Sojka *et al.,* (2007) reported that, PAM improves the soil quality by altering the physical, chemical and biological properties of soil, thereby improving aeration, water and root penetration and erosion resistance. PAM application reduced the nitrogen losses from soil and enhanced the yield of irrigated corn (Roozben *et al.,* 2012). However, less attention is given on its effectiveness on properties of soils such as pH, electrolyte level, organic matter and concentration of nutrient (N, P and K) in the rhizosphere. No-till agriculture is considered one of the important tools that increase food safety by rising production and decreasing supply degradation (FAO, 2012). Rain-fed agriculture accounts for almost 82% of world's total cropland and rain-fed farmers in semiarid regions are highly vulnerable to weather uncertainties and climate change. In arid and semi-arid region, for instance, water stress can be expected to affect rainfed crop yield once every three (Raju and Chand, 2010). Many researchers investigated the influence of tillage on the structure of soil and its hydraulic properties (An *et al.,* 2015, Reichert *et al.,* 2016, Kargas *et al.,* 2016). Most of these studies showed that, no-tillage (NT) increased infiltration of rain, decreased erosion and soil runoff, increased soil bulk density and cone index compared to the conventional tillage. Tillage system effects on important soil chemical characteristics and the differences between no-till and conventional tillage with regard to pH, EC, OM and the concentration of nutrients have been observed (Rosolem and Calonego, 2013). The presence of the nutrients in the soil depends mainly on soil type. Soil management can affect nutrient (N, P and K) concentration in soil and availability to plant roots (Rosolem and Calonego, 2013, Shekhawat *et al.,* 2016). Crop cover under no-till system greatly reduced the N losses and P fixation in the soil, increasing nitrogenous and phosphate fertilization efficiency and maintaining the nutrients balance in the system. This increase in N and labile P is a result of different interacting factors, such as minimal mixing and soil disturbance, increased residue return, reduced surface soil temperature, higher moisture content and decreased risk of

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erosion (Logan *et al.,* 1991; Blevins and Frye, 1993). Fuentes *et al.,* (2014) reported that zero tillage in both monoculture and rotation have significant effect on total nitrogen content, soil organic carbon, pH and EC, therefore, enhanced the grain yield of maize and wheat. These tillage effects, however, are environmentally dependent and different results have been reported under different types of soil and climate (Limousin and Tessier, 2007; Thomas *et al.,* 2007). Individual effect of no-till system and PAM on soil and plant growth has been investigated thoroughly, however, little information is available on its combined use and subsequent effects on plant and soil. Therefore, this study aimed to investigate the short-term individual and interaction effects of tillage and PAM application on yield and yield components of wheat and on some chemical properties of soil for two different soils with different percent of silt and clay contents.

MATERIALS AND METHODS

Experimental location and design

The experiment was conducted at the Agriculture Experimental Station of King Abdulaziz University located at Hada Alsham, northeast of Jeddah (21° 48′ 3″ N, 39° 43′ 25″ E), Saudi Arabia. A split-split block design with four replications was used in this experiment with 72 plots corresponding to the two soil textures, three tillage systems and three PAM rates.

Treatments

Three main factors (location, tillage system and PAM rate) constitute 18 treatments were investigated in this experiment. Two locations have not been cultivated for several years and different in clay and silt contents were investigated in the main blokes. Different silt and clay contents resulted in different soil physical and chemical properties. Therefore, the effect of the location on investigated parameters is due to the change in soil physical and comical properties not due to the location itself. The silt & clay contents of the first location (A) was 25.2 % while was 38.5 % in the second location (B). Table (1) presents the measured soil analysis data before starting the experiment. The sub plot included three tillage systems (NT = No-tillage, CT1 = Moldboard ploughing with rotor tiller, and CT2 = Chisel ploughing with disk harrow). The sub-sub plots included three PAM rates (0, 10 and 20 kg/ha). The three rates of polyacrylamide (PAM) were applied before planting and after applying tillage systems. The entire area of each treated plot was covered completely with PAM and mixed with the upper 15 cm soil layer by hand hoeing except for the treatment of no-tillage where the PAM was distributed on soil surface.

Cultural practices

After applying tillage systems, PAM rates and installing sprinkler irrigation system, wheat seeds were sown in rows spaced at 20 cm apart using a 10 cm-wide seed drill in all treatments with a seed rate of 135 kg ha^{-1}. After germination the plants was fertilized by the recommended doses of NPK fertilizers. Moreover, the recommended cultural practices suggested by the Ministry of Agriculture for wheat crop were followed until harvesting.

Measurements of crop yield and yield components data

Yield and yield component include: *stem length* at harvesting, number of spikes/m^2, spike length, number of grains/spike, seed yield, straw yield and seed index were measured. The measurement and determination procedures were performed as described in Kumar et al (2012) where the plant height, spike length, and number of grains per spike were recorded from 10 randomly selected plants from each plot. Total number of spikes was measured in 1 m^2 in each plot. Crop harvest was completed by using a plot combine. Total straw and grain yields of wheat crop were measured from each plot and then converted into t ha^{-1}. Seed index was obtained by taking the weight of 1000 seeds.

Soil organic matter (SOM)

Determination of soil organic matter involved the reduction of potassium dichromate ($K2Cr_2O_7$) by organic carbon compounds and subsequent determination of the unreduced dichromate by oxidation-reduction titration with ferrous ammonium sulfate.

Soil chemical properties

For initial soil analysis, four random soil samples from surface layer (0-30 cm depth homogenized soil layer) were collected from each experimental site before planting using soil auger. For the soil analyses after the end of each growing season, each plot was divided into 4 quarters, one sample was collected from the upper 30 cm soil layer of each quarter using soil auger, then, the four sample of each plot were carefully and homogeneously mixed. One complex sample was collected from the mixture, then air dried, sieved and analyzed for the investigated chemical properties. Soil pH and EC (dS m-1) was measured in 1:1 soil suspension and extraction as described by Jackson (1973). Determination of total nitrogen was done according to the Kjeldahl method (Jackson, 1973) using Kjeltec auto 1030 analyzer. Available P was determined as described in Olsen and Sommers (1982). Available K was determined as described in Carson (1980), and was measured using flame emission spectrophotometry.

Statistical analysis

The obtained data were statistically analyzed after applying the analysis of variance assumptions using SAS software. The mean separation was performed using LSD test (Steel *et al.,* 1997).

RESULTS

Effects of location, tillage system and PAM on growth and yield parameters of wheat

Results presented in Table (2) show the effects of different tillage systems and PAM rates in both locations (A and B) on growth and yield parameters of wheat. Mean comparison of growth and yield parameters under the investigated two locations (A and B) clearly indicated that, maximum plant height (66.3 cm), number of spike m^{-2} (358), spike length (9.22 cm), number of grains $spike^{-1}$ (34), grain yield (4.59 t ha^{-1}), straw yield (7.27 t ha^{-1}), and seed index (37.71 g) was observed in the soil of location B (clay and silt = 38.5%).

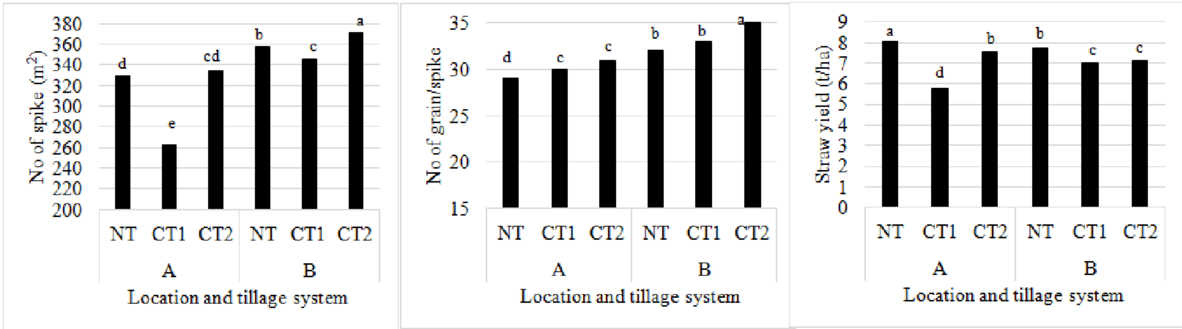

Figure 1. Number of spike/m^2, number of grain/ spike and straw yield of wheat as affected by the interaction between location and tillage system. Means followed by the same letter(s) are not significantly different according to least significant difference (LSD) test at $p \leq 0.05$

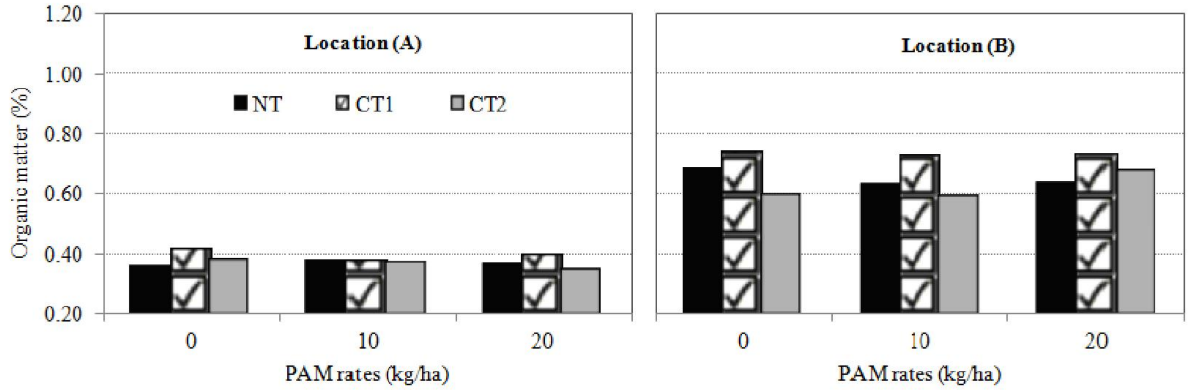

Figure 2 Effect of location, tillage system and PAM on soil organic matter (%) under wheat crop. Least significant difference (LSD) test at $p \leq 0.05$ was significant between location and not significant between PAM rates

Different trends were observed for maximum mean values of growth and yield parameters under tillage systems. No till (NT) treatment was statistically superior to moldboard ploughing with rotor tiller (CT1) and chisel ploughing with disk harrow (CT2) by producing maximum straw yield (7.90 t ha^{-1}). CT1 was better than NT and CT2 by inducing maximum plant height (67.06 cm) and seed index (39.5 g). CT2 was statistically better than NT and CT1 by yielding maximum numbers of spikes m^{-2} (353), spike length (9.43 cm), numbers of grains spike^{-1} (33) and grain yield (4.53 t ha^{-1}). Improvement in growth and yield parameters by the application of (PAM) was depend on PAM application rates. Applying 10 or 20 kg/h of PAM significantly increased number of spike m^{-2}, number of grains spike^{-1}, grain and straw yields and seed index compared with 0.0 kg/ha PAM.

Effects of 2nd level interactions on growth and yield attributes of wheat

Second level interaction between location and tillage systems was observed significant in case of number of spike m^{-2}, number of grains spike^{-1}, and straw yield. Interaction between location and PAM rate was found significant in number of spike m^{-2}, number of grains spike^{-1}, grain yield and seed index. Second level interaction between tillage system and PAM significantly affected number of spike m^{-2}, number of grains spike^{-1}, grain yield, straw yield, and seed index (Table, 2).

Interaction effect of location and tillage system

Effect of 2nd level interaction between location and tillage system on number of spikes m^{-2}, number of grains spike^{-1}, and straw yield (t ha^{-1}) is shown in figure 1. Results indicated that the highest number of spikes m^{-2} obtained under chisel ploughing with disk harrow (CT2) in both locations however, spike number in location B was higher than that of location B. the least number of spike in location A (262) and location B (345) were produced under moldboard ploughing with rotor tiller (CT1). Numbers of grain/spike were the highest in CT2 where it was higher in location B than in location A. The least numbers of grains (29 and 32) at locations A and B respectively, were found under no tillage (NT) treatment. Maximum straw yield at location A and B was achieved under NT while minimum was under CT2.

Interaction effect of location and PAM

Significant interaction between location and polyacrylamide (PAM) for their effect on number of spikes m^{-2}, number of grains spike^{-1}, grain yield (t ha^{-1}), and seeds index (g) are presented in Table (3). Increasing the rate of PAM at both locations increased all investigated parameters. However, highest numbers of spikes (388), numbers of grains (35), and grain yield (5.29 t ha^{-1}) was obtained at location B (clay and silt = 38.5%) with 20 kg PAM ha^{-1}. Only maximum value of seed index (42.96) was observed at location A (clay and silt = 25.2%) with 20 kg PAM ha^{-1}.

Interaction effect of tillage system and PAM

Results presented in Table (4) showed an improvement in numbers of spike m^{-2}, number of grains spike^{-1}, grain yield, straw yield, and seed index by the interaction between tillage system and PAM.

Table 1. Initial physical and chemical soil analyses before the starting of the experiment

Parameter	Values	
	Location (A)	Location (B)
Particle size analysis		
Clay %	9.7	12.8
Silt %	15.5	25.7
Sand %	74.8	61.5
Texture grade	Sandy loam	Sandy loam
Penetration resistance		
Layer 0-15	Moderate compacted	Slightly compacted
Layer 15-30	compacted	compacted
Layer 30-45	compacted	compacted
Bulk density (g/cm^3)	1.87	1.71
Air porosity (%)	29.4	35.4
Basic infiltration rate (cm/hour)	16.0	7.0
Organic matter (%)	0.65%	1.10%
EC $_{(1:1\ soil\ extraction)}$ ($dS\ m^{-1}$)	0.366	9.16
pH$_{(1:1\ soil\ suspension)}$	7.70	7.32
Nitrogen (%)	0.03	0.08
Phosphorus (mg kg^{-1} soil)	6	13
Potassium (mg kg^{-1} soil)	475	1140

Table 2. Effect of location, tillage system and PAM rate on growth and yield attributes of wheat

Treatments	Plant height (cm)	Number of spike m^{-2}	Spike length (cm)	Number of Grains/ spike^{-1}	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Seed index (g)
Location (L)							
A	65.55 ^{a}	308.5^b	9.12 ^{a}	30.05^b	3.75^b	7.13^a	40.37^a
B	66.30 ^{a}	357.9^a	9.22 ^{a}	33.84^a	4.59^a	7.27^a	37.71^b
LSD	NS	4.39	NS	0.50	0.28	NS	1.61
Tillage system (TS)							
NT	66.25 ^{a}	343.4^b	9.34^a	31.05^c	4.16^b	7.90^a	38.6 ^{a}
CT1	67.06 ^{a}	303.4^c	8.73^b	31.83^b	3.82^c	6.43^c	39.5 ^{a}
CT2	64.47 ^{a}	352.8^a	9.43^a	32.96^a	4.53^a	7.27^b	39.0 ^{a}
LSD	NS	8.53	0.346	0.721	0.14	0.189	NS
Polyacrylamide (PAM) rates (kg ha^{-1})							
0.0	64.93 ^{a}	314.3^b	9.07 ^{a}	30.80^b	3.39^b	6.82^c	35.32^b
10.0	65.40 ^{a}	341.1^a	9.13 ^{a}	32.25^a	4.51^a	7.22^b	40.54^a
20.0	67.45 ^{a}	344.2^a	9.30 ^{a}	32.80^a	4.60^a	7.57^a	41.27^a
LSD	NS	8.35	NS	0.698	0.149	0.327	0.149
Significance							
L	NS	**	NS	**	**	NS	*
TS	NS	**	**	**	**	**	NS
PAM	NS	**	NS	**	**	**	**
L*TS	NS	**	NS	**	NS	**	NS
L*PAM	NS	**	NS	**	**	NS	**
TS*PAM	NS	**	NS	**	**	**	**
L*TS*PAM	NS	**	NS	*	NS	NS	NS

A: clay and silt = 25.2%, B: clay and silt = 38.5%, NT: no tillage, CT1: moldboard ploughing with rotor tiller, CT2: chisel ploughing with disk harrow, ns: not significant ($p \leq 0.05$), * and ** significant at $p \leq 0.05$ and $p \leq 0.01$, respectively. Means followed by the same letter(s) are not significantly different according to least significant difference (LSD) test at $p \leq 0.05$.

Table 3. Interaction effect of location and PAM rate on number of spikes m^{-2}, number of grains spike-1, grain yield (t ha-1), and seeds index (g)

Location	PAM rate (kg ha^{-1})	Number of spikes m^{-2}	Number of grains spike^{-1}	Grain yield (t ha^{-1})	Seed index (g)
A	0	300^d	28^e	3.14^e	37.44^c
	10	302^d	31^d	3.74^d	40.71^b
	20	324^c	31^d	4.37^c	42.96^a
B	0	327^c	33^c	3.64^d	33.20^d
	10	358^b	34^b	4.83^b	39.58^b
	20	388^a	35^a	5.29^a	40.37^b
LSD		*11.88*	*0.99*	*0.21*	*1.15*

A: clay and silt = 25.2%, B: clay and silt = 38.5%. Means followed by the same letter(s) are not significantly different according to least significant difference (LSD) test at $p \leq 0.05$.

However, the enhancement in growth and yield parameters by the application of PAM under each tillage system was dependent on PAM application rate. Increasing the amount of PAM showed additive effect on all the studied parameters under each tillage system. Maximum numbers of spikes (376) and number of grains (35) were obtained from chisel ploughing with disk harrow (CT2) along with 20 kg PAM ha^{-1}. Highest grain yield (4.91t ha^{-1}) and straw yield (8.74 t ha^{-1}) was recorded in the treatment of 20 kg PAM ha^{-1} under no tillage (NT) treatment. Seed index was the highest under 20 kg PAM ha^{-1} of moldboard ploughing with rotor tiller (CT1).

Effect of location, tillage system and PAM on soil organic matter: Results of soil organic matter presented in Figure (2) revealed that, both locations were significantly different from each other in organic matter contents.

Table 4. Number of spikes, number of grains/spike, grain and straw yields and seeds index (g) as affected by the interaction effect of tillage system and PAM rate

Tillage system	PAM rate (kg ha^{-1})	Number of spikes m^{2}	Number of grains spike^{-1}	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Seed index (g)
NT	0	331^{cd}	28^{e}	3.02^{d}	7.39^{b}	32.95e
	10	337^{c}	32^{cd}	4.55^{b}	7.57^{b}	41.09^{ab}
	20	361^{b}	33^{bc}	4.92^{a}	8.74^{a}	41.76^{ab}
CT1	0	289^{f}	31^{d}	3.17^{d}	6.11^{d}	35.17^{d}
	10	302^{e}	31^{d}	4.13^{c}	6.55^{d}	41.10^{ab}
	20	319^{d}	33^{bc}	4.15^{c}	6.64^{d}	42.22^{a}
CT2	0	322^{d}	33^{bc}	3.99^{c}	6.77^{cd}	37.83^{c}
	10	360^{b}	34^{ab}	4.73^{ab}	7.33^{bc}	38.76^{c}
	20	376^{a}	35^{a}	4.86^{a}	7.72^{b}	40.49^{b}
LSD		*14.55*	*1.22*	*0.26*	*0.57*	*1.41*

NT: no tillage, CT1: moldboard ploughing with rotor tiller, CT2: chisel ploughing with disk harrow. Means followed by the same letter(s) are not significantly different according to least significant difference (LSD) test at $p \leq 0.05$.

Treatments	Soil EC (dS m^{-1})	Soil pH	Total N (%)	Available P (mg kg^{-1})	Available K (mg kg^{-1})
Location (L)					
A	1.31^{b}	7.47^{a}	0.016^{b}	25^{b}	442^{b}
B	4.04^{a}	7.51^{a}	0.053^{a}	34^{a}	713^{a}
LSD	*0.46*	*NS*	*0.032*	*7.01*	*67.22*
Tillage system (TS)					
NT	2.47^{a}	7.51^{a}	0.025^{a}	26^{a}	675^{a}
CT1	2.91^{a}	7.47^{a}	0.030^{a}	31^{a}	636^{a}
CT2	2.65^{a}	7.48^{a}	0.039^{a}	26^{a}	644^{a}
LSD	*NS*	*NS*	*NS*	*NS*	*NS*
Polyacrylamide (PAM) rates (kg ha^{-1})					
0.0	2.578^{a}	7.40^{a}	0.017^{b}	20^{b}	555^{b}
10.0	2.712^{a}	7.48^{a}	0.032^{a}	21^{b}	559^{b}
20.0	2.760^{a}	7.52^{a}	0.055^{a}	42^{a}	618^{a}
LSD	*NS*	*NS*	*0.025*	*7.41*	*51.36*
Significance					
L	**	*NS*	*	*	**
TS	*NS*	*NS*	*NS*	*NS*	*NS*
PAM	*NS*	*NS*	*	**	*
L*TS	*NS*	*NS*	*NS*	*NS*	*NS*
L*PAM	*NS*	*NS*	*NS*	*NS*	*NS*
TS*PAM	*NS*	**	*NS*	*NS*	**
L*TS*PAM	*NS*	*NS*	*NS*	*NS*	*NS*

A: clay and silt = 25.2%, B: clay and silt = 38.5%, NT: no tillage, CT1: moldboard ploughing with rotor tiller, CT2: chisel ploughing with disk harrow, ns: not significant ($p \leq 0.05$), * and ** significant at $p \leq 0.05$ and $p \leq 0.01$, respectively. Means followed by the same letter(s) are not significantly different according to least significant difference (LSD) test at $p \leq 0.05$.

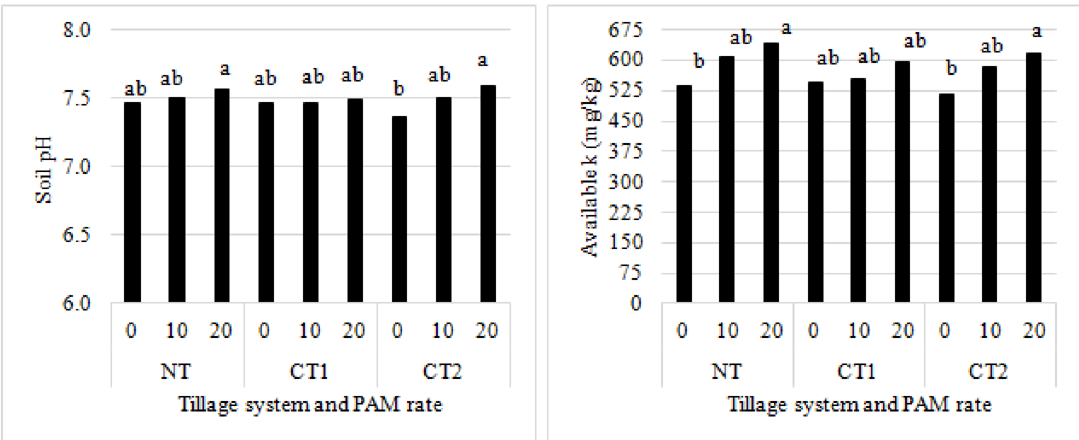

Figure 3. Soil pH and available potassium as affected by the interaction between tillage system and PAM rates under wheat crop. Means followed by the same letter(s) are not significantly different according to least significant difference (LSD) test at $p \leq 0.05$

Location B (clay + silt = 38.5%) had higher organic matter content than location A (clay + silt = 25.2%) under all tillage systems and PAM rates. Different tillage systems also showed significantly different effect on soil organic matter. However, maximum organic matter in both locations and at all levels of PAM was observed under CT1 (moldboard ploughing with rotor tiller).

Different rates of PAM (0, 10 and 20 kg ha^{-1}) showed insignificant difference on soil organic matter in both locations and under all tillage systems.

Effects of location, tillage system and PAM on soil pH, EC, total N and available P and K

Results of the effect of tillage system and PAM on soil EC, pH, total N and available P and K at both locations are presented in Table (5). Results indicated that, only the locations were significantly different in soil EC. Location B (clay and silt = 38.5%) was having remarkably higher EC (4.04) than location A (clay and silt = 25.2%). pH insignificantly affected by the investigated parameters. However, 2nd level interaction between tillage system and PAM was significantly affected on soil pH. Comparing means of total N and available P and K in both locations revealed that, the highest total N (0.053%), available P (34 mg kg^{-1}) and K (713 mg kg^{-1}) were found in location B. When means of total N and available P and K were compared under different PAM rates, it was observed that, increasing the rate of PAM application increased nutrients availability. Maximum value of total N (0.055%), available P (42 mg kg^{-1}) and K (618 mg kg^{-1}) was recorded under the application of 20 kg PAM ha^{-1}.

Interactions effect of tillage system and PAM with soil pH and available K

Means of soil pH and available K as influenced by the interaction between tillage systems and PAM rates are shown in Figure (3). Increasing PAM application rate increased soil pH and available K under all the tillage systems. The highest pH (7.59) was observed under chisel ploughing with disk harrow (CT2) and 20 kg ha^{-1} PAM. Lowest pH (7.36) was also observed under CT2 but with 0 kg ha^{-1} PAM. Soil available K was also varied significantly under the interaction effect of tillage systems and PAM rates. Highest available K (643 mg kg^{-1}) was recorded under no tillage (NT) with the application of 20 kg ha^{-1} PAM. Lowest available K contents (515) were observed under CT2 with 0 kg ha^{-1} PAM.

DISCUSSION

Promotion of all the growth and yield parameters of wheat except seed index has been observed at Location B (clay and silt = 38.5%) more than at location A (clay and silt = 25.2%). The improvement in growth and yield of wheat at location B could be attributed to soil texture. Higher percentage of fine particles (38.5 silt + clay) especially clay in location B than that of location A (25.2 silt + clay) considered the main reason for the improvement in growth and yield of wheat. presence of fine soil particles have been reported to improve water retention (Ismail, 2004), water holding capacity, (Reuter, 1994) and reduce plant nutrient losses, (Ismail and Ozawa, 2007) which ultimately enhance crop growth and yield (Obst, 1989; Carter *et al.,* 1998). Besides this, fine soils also retain more organic matter, which play great role in improving crop growth and yield. The presence of significantly higher organic matter in location B than in location A can further strengthen this premise. Improvement in soil structure, aggregation, water holding capacity and nutrient availability were always accompanied with increasing the contents of soil organic matter, (Tanaka *et al.,* 2005; Narayan and Lai, 2006, Ismail 2013).

Regarding tillage systems, chisel ploughing with disk harrow (CT2) was better compared with the others. It was produced the maximum growth parameters because the enhancement in numbers of spikes m^{-2}, spike length, numbers of grains spike^{-1}, and grain yield was observed under this system. As a result, high yield was produced. Higher grain yield obtained under CT2 might be resulted due to concomitant improvement in yield related attributes such as numbers of spikes m^{-2}, spike length and numbers of grains spike^{-1} under CT2. Several researchers (Stoddard, 1999; Duggan and Fowler, 2006; Royo *et al.,* 2006) published that, yield related parameters like number of plants per unit area, spikes per plant, spikelets per spike and grains per spikelet were greatly affect on grain yield. Another possible reason for the enhancive effect of CT2 on yield and yield related parameters could be positive influence of CT2 on soil fertility properties. Chisel ploughing increased nitrate concentration by about 42% compared to 29% under moldboard ploughing and to non-plowed soil (Calderon and Jackson, 2002). Increasing nitrate concentration in soil increased plant growth and productivity.

Increasing PAM rate increased yield and yield components of wheat crop compared to control. Presence of PAM in soil expected to improved hydraulic conductivity, infiltration rate, aeration, aggregate stability. The improvement in these characteristics might be encouraged root penetration, thereby boosts plant establishment and growth (Flanagan *et al.,* 2003). Also, incorporated PAM in soil can reserve available water and maintain sufficient soil moisture for plants, therefore decreases water stress during drought events and increase the efficiency of water use by increasing crop production (Lentz and Sojka, 2009; Awad *et al.,* 2013; Lee *et al.,* 2015). The relatively higher organic matter contents recorded at location B might be due to intrinsic nature of fine particles. The soils having higher proportion of fine particles (clay + silt) may retain more organic matter than course particle soils. On the other hand, low organic matter is generally found in sandy soils due more oxidation of organic matter through high aeration. Tillage treatment significantly affected the organic matter content of the soils in the two locations. Tillage reduces SOM by different ways. Tillage removes plant residue from the soil, thus limiting the normal cycling of material in the system. Tilling may provide air that enhances the rate of microbial decomposition. Furthermore, tillage breaks up soil aggregates, which have a significant function in stabilizing SOM. When soil aggregates are split up, SOM becomes much more susceptible to degradation and succeeding loss. Significantly higher EC at location B (clay + silt = 38.5%) than location A generally attributed to higher clay contents. Charge bearing property of clay particles can bind different cations and anions resulting in higher EC. Whereas in soils with high proportion of sand particles, cations and anions of salts can be leached due to poor binding capacity of sand particles. Similarly, significantly more total N and available P and K at location B could be also associated with high fine particles and mainly due to two reasons. Firstly, due to high nutrient retention by fine soil particles and secondly due to high organic matter contents in such soils. Similar results reported by Franchini *et al.,* (2003); Pavinato and Rosolem (2008),who reported that, organic matter increases the percentages of calcium (Ca), magnesium (Mg), and K in the soil cation exchange capacity (CEC) due to the complexation of ions, which can reduce nutrient losses due to leaching, especially K. In this study PAM with a rate of 20 kg ha^{-1} significantly enhanced total N and available P and K of soil. The results could be attributed to the improvement of soil physical and chemical. Several studies showed that, small rate of synthetic organic polymers, including anionic polyacrylamide (PAM), can improve soil structure and aggregate stability, bonding between adjacent aggregates and clay flocculation (Peterson *et al.,* 2002; Graber *et al.,* 2006; Sojka *et al.,* 2007). Application of PAM improved vertical movement of soil water and major/minor nutrients (NH_3-N, P, K, Ca, Mg, and Fe) which enhanced the nutrient availability for plants (Kim *et al.,* 2015)

Conclusion

The obtained results showed significant improvement in growth and yield parameters of wheat in Location B compared with those of location A. Chisel ploughing with disk harrow (CT2) significantly improved number of spike m^{-2}, spike length, number of grains spike^{-1} and grain yield compared with NT and CT1 tillage systems. Number of spikes m^{-2}, number of grains spike^{-1} and straw yield were increased as affected by the interaction between location and tillage system and the interaction between tillage system and PAM. However, the interaction between location and PAM increased number of spikes m^{-2}, number of grains spike^{-1}, grain and seed index. Significantly higher organic matter contents, EC, total N and available P and K were observed in location B compared with location A. Tillage systems did not show significant effect on any of the soil chemical property and soil nutrient. Application of PAM (20 kg ha^{-1}) improved total N and available P and K in soil. In conclusion, using of Chisel ploughing with disk harrow (CT2) and high rate of PAM (20 kg ha^{-1}) could be a potential strategy to improve wheat production in arid regions.

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