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Full Length Research Paper

“A study of the impact of irrigation with different intensities on potassium efficacy and increased yield of wheat autumn cultivation in loessal soils with high specific surface area and electrical truncated diffuse double layers”

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In order to examine the effect of irrigation on wheat yield with a high specific surface area in a soil comprising illite clay that causes reduced usability of potassium for wheat and loss in potassium absorption and yield, three dry- farming treatments (which includes transparent, black mulches and non- plastic mulch) and irrigated treatments (consist of saturated flooding and unsaturated rain and drop irrigations) were compared in a completely randomized block design within three repeated processes, after applying basal fertilizer from potassium and nitrogen composition in all treatments. Intensity rates of flooding, rain- water and dropping types of irrigation were 240, 144 and 60 mm/h, respectively and every plot was irrigated with 140 mm of water during an interval of 6 months each time. Potassium absorption and a number of clusters were increased with three irrigated treatments than dry-farming treatments in biological yield and per unit of area. It is likely that moisture may improve potassium diffusion intensity toward roots and increase its usability. Increasing humidity by soil reduced mechanical resistance may also result in improvement of roots’ development, potassium absorption and number of clusters and yield at the unit area. Among irrigated treatments, the maximum density of soil nitrate, nitrogen absorption and biological yields resulted from flooding treatment. Probably, by flooding method (with maximum intensity of irrigation), water depth penetration might be lower than that in two other techniques (unsaturated irrigation methods) and this caused lesser washing nitrate and further improved its yield. It is probable that yield of irrigation treatments is a function of usability of soil nitrogen.

Key words: Wheat, soil with high specific surface area, illite clay, intensity of irrigation, nutrients.

INTRODUCTION

One may refer to using potential of producing water and soil sources and their survey for production, sustainable development and making effort to improve yield and enrichment of farming crops, as one of the foremost goals of the countries in the third millennium, in order to improve food quality in the course of achieving standards in public health principles. Since soil plays several roles in plant’s life, soil-plant reciprocal effect cannot be ignored. Soil is a location for lodging of plant’s roots and it provides air (oxygen), water and other elements for the plant. Potassium (K) is mostly a consuming essential element and is deemed as the most frequent cations in higher plants. In addition to vital physiologic tasks which this element has in plant, it has allocated special position to itself in improving quality of agricultural crops as well, such that, it is called a quality element. Potassium is the fourth nutrient and a frequent element in soil that forms

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about 2.5% of lithosphere. Real density of this element varies in soil within a wide range and its range is approximately 0.04 to 3% (Sparks and Huang, 1985). This nutrient is found within four different forms in soil; soluble potassium in soil, exchanged and non- exchanged potassium and the existing potassium within mineral lattice (Syers, 1998).

Availability of potassium for plants depends on intensity, capacity and speed of it renewability in soil. Intensity includes potassium density in soluble soil. Capacity denotes total existing potassium on soil cation exchange capacity (CEC) that is converted into usable substance for the plant by ingress into soil solution, and new speed refers to a synthetic factor, which illustrates potassium transfer speed from capacity to intensity (Barber, 1972). Unfortunately, improper consumption of azotic and phosphate fertilizers and non- allocation of other nutrients to fertilizer compounds have caused the exacerbated deficiencies and reduce fertilization of soils. Clay in most of the tested loessal soils with clay origin has a lot of illite. This clay can provide the needed potassium for plant in production of farming crops at medium level. However, potash fertilizer should be used for high level production (Havlin et al., 2005).

Illite clay layers may be blocked by drying and this causes limited use of potassium for the plant. In the analysis of potassium higher quantities for extraction by ammonium acetate and its higher densities (concentrations) within the soils with specific surface area in test site, potassium slow diffusion (exchange of potassium) and the existing synthetic exchange potassium in diffusion double layer (DDL) may hinder plant adequate absorption and lead to reduced yield (Amini, 2006; Sebti et al., 2009; Talebizadeh, 2009; Faeznia, 2004).

In the present study, through exertion of different irrigation intensities by means of flooding, rain water and dropping techniques of irrigation as well as, using black and transparent mulches, potassium absorption and wheat yield have been assessed. Irrigation and mulch may affect availability of elements provided for the plant by creating different humid and thermal environments. The present research was intended to answer this question as to whether one might still increase wheat yield through saturated and unsaturated irrigations at different intensities by consuming azotic- potassium based fertilizers within all tested treatments or not.

MATERIALS AND METHODS

This study was conducted in the research farmland of Gorgan University of Agricultural Sciences and Natural Resources, which is situated on 54°30´E and 37°45´N. This study was carried out in a farmland not in a glasshouse (vase) because hydrothermal properties differ in farmland conditions from vase environment. There is no draining operation in vase and moisture is reduced more slowly than in lands and rate of potassium diffusion and its usability extremely depends on soil humidity and heat. Thus, it is possible that potassium does not act as a restriction factor in vase conditions. Field soil has been classified according to American classification (*Typic Haploxerept*). By application of ethylene glycol mono ethyl ether, soil specific surface area was measured (Carter et al., 1986). After selection of the given land plot and execution of two- way rocker plowing and by disk type on December 2nd 2008, a composed sample was prepared from zero depth to 30 cm from ground level and it was dried after transfer to air lab where physical and chemical experiments were carried out on them. On the same date, Zagros wheat seeds were planted in some plots with 4 × 6 m dimensions. Seeds were sprouted on 14th January. 200 kg urea fertilizer were consumed per hectare where half this quantity were used first with 200 kg potassium sulfate fertilizer before cultivation and the rest urea fertilizer was added to soil on 10th day of March. Trial project was repeatedly carried out three times with 7 treatments (including dry-farming and irrigation types) within a completely random plan. Dry-farming treatments comprised of cultivation with plastic, black and transparent mulches among the rows and without mulch and treatment without (control group) cultivation; and irrigated treatments consisted of unsaturated dropping irrigation (with 60 m/h intensity), unsaturated rain-water type (144 mm/h) and flooding saturated treatment (240 mm/h). Irrigation was carried out at three phases before clustering on 6th, 13th and 24th March, 2008 and at three times after clustering on May 1st, 9th and May 22nd 2009. The quantity of transferred water was 3.3 m^3 in any plot at each step which is equal to 137 mm water. Dropping, rain-water and flooding irrigation systems included water transfer system and the needed equipments for realization of study goals, which were installed on 28/02/2009 and plastic, black and transparent mulches with 20 cm width and similar holes (to penetrate rain-water) were inserted within intervals in cultivation rows on 20/01/2009. However, through construction of water transfer equipments and water pumps, irrigation treatments were built. Thereafter, with the aid of fixed round sprinklers, rain water irrigation was designed identically in three plots.

Through construction of surface spectra along each row with drapers at 20 cm intervals, dropping irrigation was planned and implemented and finally, flooding irrigation was done normally by releasing water uniformly over the plot surface. The value of specific surface area was measured 132 m^2/g for the given soil (Carter et al., 1986). Soil moisture was measured in zero depth to 15 cm and 15 to 30 cm and in plant organ during cultivation period at 6 steps. To conduct chemical syntheses, samples were derived from rhizosphere and soil up to 30 cm depth and exactly from place of taking plant samples and also of the plant simultaneously on April 16th 2009 (before clustering) and June 17th 2009 (at the end of maturing of wheat). About 40 samples were extracted from the upper leaves of four plants before the clustering phase. On 18/04/2010, one meter soil sample was extracted as cut-floor for measurement of the elements such as nitrogen, phosphorus, potassium, magnesium and calcium (Emami, 1996). Quantities of salinity, acidity, organic carbon and soil exchange capacity and texture were measured (Aliehyaei and Behbahani, 1993). To determine wheat yield and its elements, sampling was done on 1 cubic meter of surface of trial plot. The given design was carried out within completely random blocks and data analysis by SAS software and through comparison of mean data according to Fisher's least significant difference (LSD) test at 5% level.

RESULTS AND DISCUSSION

The consuming water in this experiment was supplied from a well in this region where electrical conductance (EC) of this water was 0.65 deci-siemense on 11th August, 2009, residual sodium carbonate (RSC) as 0.5

Table 1. Water chemical properties.

Classification	Residual sodium carbonate (RSC) (meq/L)	Sodium absorption ratio (SAR)	Hardness	Total cations (me/l)	meq/L								Acidity	Total dissolvable salts (TDS) (mg/L)	Electric conductancen (Ds/m)
					Na^+	Mg^{++}	Ca^{++}	Total anions	Cl^-	SO_4^{--}	HCO_3^-	CO_3^{--}			
c2S1	0.5	0.2	280	5.9	0.3	2.4	3.2	6.7	0	0.6	6.1	0	7.5	416	0.65

Table 2. Soil physico- chemical properties (depth 0 to 30 cm).

Soil texture	Sand (%)	Silt (%)	Clay (%)	Azote nitrate	Ammonium Azote	Absorbable potassium by tetra phenyl borane sodium (ppm)	Organic carbon (O%)	Total neutral materials (TNV%)	Absorbable potassium by ammonium acetate (ppm)	Absorbable phosphorous (ppm)	Acidity of saturated vase	Electric conductance (Ds/m)
Silty clay loam	10	56	34	13.3	0	620	0.96	24	350	11.2	7.3	0.7

Equivalence/Lit and sodium absorption ratio (SAR) was 0.2 $mmol^2/L^2$ (Table 1).

The results of some physical and chemical syntheses of sample in the test site were derived in zero surfaces up to 30 cm from ground level. Values of acidity, soil electrical conductance, absorbable phosphorus and azotic nitrate were at favorable level for growth of wheat. According to the study of Havlin et al. (2005) with 13 to 15 mg/kg soil nitrate in zero surfaces up to 30 cm, there is no need for azotic fertilizer for production of 6 tons per hectare for wheat. Also, with 12 mg/kg phosphorus, there is no need to add phosphate fertilizer. It seems the given form for nitrogen belongs to colder regions in Gorgan city and for those areas with Gorgan climatic conditions where synthesis of organic substances is done more quickly it requires using azotic fertilizer and probably in higher quantity. The quantity of absorbable potassium was 350 mg/kg with acetate, so based on the study of Havlin et al. (2005), there is no need to add azotic fertilizer with more than 160 mg/kg potassium. However, due to high specific surface and abundant illite clay in the tested soils, wheat yield will be improved through addition of fertilizer to soil. Soil texture within zero surfaces up to 30 cm is the area of developing wheat in loamy-silty clay (Table 2). After execution of all three irrigation treatments, chaffs yield was greater than three dry-farming treatments (Table 3). Also, grain yield was increased greatly with flooding and dropping treatments than with three dry-farming treatments. Apparently, irrigation by flooding, rain-water and dropping treatments may increase number of clusters in the unit area (Table 3) and yield as well.

According to Table 4, during all dates of measurement after the first irrigation on March 6th 2009, three irrigation treatments possessed the highest humidity at both sampling depths (0 to15 cm and 15 to 30 cm). Probably, the presence of black plastic caused reducing temperature and increase of moisture in soil profile. Yield of grain and chaff was greater with black plastic mulch and farming treatments than with transparent plastic mulch. Also, potassium absorption by these two treatments was higher than with transparent plastic mulch. History of the studies (Amini, 2006; Sebti et al., 2009; Talebizadeh, 2009; Faeznia, 2004) *in vitro* indicates that potassium is the foremost inhibitor factor for wheat growth on test site. With respect to Tables 5, 6 and 7, it seems that increase in soil humidity and potassium diffusion intensity by irrigation treatments may remove limitation of absorbable potassium in soil. It seems improbable to increase yield by irrigation via reduction of water stress since according to Minimum Rule, the limitation, as the foremost inhibitive factor of plant’s growth (that is, potassium) should be reduced in order to increase yield. In irrigation treatment, nitrogen absorption was increased by rising of dropping, rain-water and flooding treatments of chaff yield, respectively.

With respect to Table 8, it seems that through three irrigation treatments, quantity of soil nitrate is lesser than in dry-farming treatments and this may lead to limiting nitrogen for wheat growth by irrigation treatments. By means of greater intensity, flooding irrigation treatment may wash soil nitrate lesser. By adding water fixed depth to soil and through unsaturated irrigations, penetration depth and moving minerals are higher than with mass flow and its density is lesser in soil (Hillel,

Table 3. Comparison of plant's growth mean index.

Treatment	Compared of average									
	Mean fertilized stem in bush	Mean spikelet in bush	Mean length of stem	Mean seed per cluster	Cluster no. in 1 m^2	Grain weight per thousand g	Chaffs yield (kg/h)	Seed yield (kg/h)	Biologic yield (kg/h)	Index (%)
Drop irrigation	4.53^{c}	75.40^{a}	93.26^{a}	30.6^{c}	535.5^{c}	38.17^{b}	4210^{b}	3420^{b}	7630^{c}	44
Rainwater irrigation	4.73^{b}	$63.\ 8^{c}$	87.5^{c}	28.90^{d}	571.2^{a}	37.29^{c}	4480^{a}	3350^{c}	7830^{b}	42
Flood irrigation	4.80^{a}	66.7^{b}	90.1^{b}	33.36^{b}	557.4^{b}	40.52^{a}	4550^{a}	3770^{a}	8320^{a}	45
Black plastic	4.40^{d}	62.2^{d}	85.2^{d}	40.01^{a}	524.7^{d}	31.74^{e}	3730^{c}	3370^{c}	7100^{d}	47
Transparent plastic	4.06f	59.40^{e}	89.7^{b}	26.67^{e}	454.3^{e}	37.41^{c}	3440^{d}	2860^{d}	6300^{e}	45
Dry-farming treatment	4.13^{e}	63.80^{c}	85.50^{e}	32.70^{b}	451.1^{e}	35.12^{d}	3780^{c}	3330^{c}	7110^{d}	46
LSD	0.05	0.92	0.69	0.77	8.61	0.5	75.05	48.06	117.5	0.002

Mean values in each column with at least one similar letter have no significant difference at 5% level, according to LSD test.

Table 4. Comparison of mean humidity in both (0-15) and (15-30) cm depth of soil.

Treatment	Depth: 0 to 15 cm					Depth: 15 to 30 cm				
	27/02/2009	24/03/2009	1/05/2009	15/05/2009	30/05/2009	27/02/2009	24/03/2009	1/05/2009	15/05/2009	30/05/2009
Drop irrigation	25.99^{a}	23.83^{a}	23.09^{b}	25.30^{b}	24.93^{b}	25.99^{a}	24.33^{a}	24.01^{b}	25.17^{b}	25.89^{a}
Rainwater irrigation	23.55^{ab}	22.46^{ab}	25.15^{a}	25.31^{b}	22.82^{c}	23.55^{ab}	23.87^{a}	25.13^{a}	24.64^{c}	23.54^{b}
Flood Irrigation	22.78^{ab}	22.05^{abc}	23.02^{b}	26.54^{a}	25.46^{a}	22.78^{ab}	22.13^{c}	22.77^{c}	25.93^{a}	23.50^{b}
Black plastic	22.86^{ab}	17.81^{dc}	19.51^{f}	13.98^{c}	19.42^{d}	22.86^{ab}	20.35^{bc}	18.93^{a}	14.83^{f}	15.15^{c}
Transparent plastic	22.85^{ab}	17.70^{d}	20.16^{e}	13.32^{d}	15.50^{g}	22.85^{ab}	18.59^{c}	20.59^{f}	15.57^{e}	14.83^{c}
Dry-farming treatment	20.93^{b}	16.58^{d}	22.24^{c}	14.28^{c}	17.91^{e}	20.93^{b}	19.22^{c}	20.98^{e}	15.21^{ef}	1356^{d}
Without culture	23.58^{ab}	18.43^{bcd}	21.84^{d}	12.71^{e}	17.2^{f}	22.58^{ab}	21.11^{bc}	21.91^{d}	16.24^{d}	14.93^{c}
LSD	3.28	4.25	0.11	0.50	0.38	3.2	2.6	0.12	0.41	0.51

Mean values in each column with at least one similar letter have no significant difference at 5% level, according to LSD test.

1980). Probably, lesser quantity of soil nitrate in irrigated treatments is partially due to increased nitrogen absorption in such treatments since density of potassium as an unmoving element (by tetra phenyl sodium borane) is also lesser in irrigated treatment than dry-farming type. Quantity of nitrate and soil potassium (tetra phenyl sodium borane) with transparent plastic mulch is greater than in other treatments and this may be due to higher soil heat in this treatment and high speed of synthesis of soil organic materials. Absorption of nitrogen and potassium with this treatment was not greater than in other dry-farming treatments and this is probably because of the negative effect of high soil temperature on metabolic activities in root and elements absorption.

Conclusion

Increase in soil humidity with irrigation treatments caused increased potassium absorption and yield. With respect to high specific surface area of soil on test site, development of electrical diffusion double-layer was not complete (dissociated) and as a result, the major part of water-soil is placed

Table 5. Comparison of elements average density in grain (percent).

Treatments	**Percentage**				
	Potassium	**Calcium**	**Magnesium**	**Phosphorous**	**Azote (nitrogen)**
Drop irrigation	0.560^{a}	0.120^{b}	0.160^{b}	0.451^{b}	2.14^{e}
Rainwater irrigation	0.540^{c}	0.110^{c}	0.150^{c}	0.461^{a}	2.51^{a}
Flood Irrigation	0.560^{a}	0.070^{e}	0.170^{a}	0.421^{c}	2.36^{b}
Black plastic	0.540^{c}	0.120^{b}	0.150^{c}	0.412^{d}	2.39^{b}
Transparent plastic	0.550^{b}	0.090^{d}	0.160^{b}	0.421^{c}	2.29^{c}
Dry-farming treatment	0.560^{a}	0.130^{a}	0.140^{d}	0.422^{c}	2.22^{d}
LSD	0.0018	0.0041	0.0019	0.0027	0.021

Table 6. Comparison of mean extraction of elements in grain and chaff (kg/h) with respect to yield of grain and chaff.

Treatment	**Grain (kg/h)**					**Chaff (kg/h)**				
	Potassium	**calcium**	**magnesium**	**phosphorus**	**Nitrogen (azote)**	**Potassium**	**calcium**	**magnesium**	**phosphorus**	**Nitrogen (azote)**
Drop irrigation	19.37^{b}	4.14^{b}	5.53^{b}	15.39^{b}	73.19^{d}	87.9^{b}	14.89^{b}	5.10^{c}	6.73^{a}	25.26^{d}
Rainwater irrigation	18.20^{d}	3.71^{c}	5.05^{c}	15.41^{b}	83.75^{b}	85.1^{c}	13.55^{c}	6.32^{b}	6.27^{b}	34.49^{b}
Flood irrigation	21.29^{a}	2.66^{d}	6.46^{a}	15.83^{a}	88.97^{a}	102.8^{a}	21.56^{a}	6.88^{a}	6.37^{b}	40.49^{a}
Black plastic	18.41^{d}	4.09^{b}	5.11^{c}	13.82^{c}	80.21^{c}	77.2^{d}	10.18^{d}	3.39^{e}	3.73^{e}	16.03^{f}
Transparent plastic	16.04^{e}	2.62^{d}	4.23^{c}	12.01^{d}	65.21^{e}	63.9^{f}	10.06^{d}	3.46^{e}	4.81^{c}	20.29^{e}
Dry-farming treatment	18.81^{c}	4.36^{a}	4.67^{d}	13.99^{c}	73.93^{d}	68.7^{e}	8.82^{e}	4.21^{d}	4.14^{d}	29.86^{c}
LSD	0.393	0.135	0.133	0.24	1.42	2.36	0.538	0.226	0.21	1.51

Mean values in each column with at least one similar letter have no significant difference at 5% level, according to LSD test.

Table 7. Comparison of mean extraction of elements in grain and chaff (kg/h) with respect to biologic yield.

Treatment	**Percentage**					
	Total potassium	**Total calcium**	**Total magnesium**	**Total phosphorus**	**Total azote**	**Total yield**
Drop irrigation	108.33^{b}	19.00^{b}	11.00^{b}	22.66^{a}	99.66^{d}	7716.67^{c}
Rainwater irrigation	104.33^{c}	17.00^{c}	11.00^{b}	21.66^{b}	119.33^{b}	7893.33^{b}
Flood irrigation	125.00^{a}	24.33^{a}	13.33^{a}	22.66^{a}	130.66^{a}	8393.33^{a}
Black plastic	96.33^{d}	14.00^{d}	8.33^{c}	18.00^{c}	97.33^{e}	7183.33^{d}
Transparent plastic	80.66^{f}	13.00^{e}	8.33^{c}	17.00^{d}	87.33^{f}	6390.00^{e}
Dry-farming treatment	88.66^{e}	13.00^{e}	9.00^{c}	18.66^{c}	104.66^{c}	7196.67^{d}
LSD	1.08	0.428	0.742	0.79	0.021	25.22

Table 8. Comparison of mean density of elements on soil at extraction phase (mg/kg).

Treatments	Phosphorous	Ammonium	Nitrate	Potassium (tetra phenyl boron sodium)	Calcium	Magnesium
Drop irrigation	7.53^{g}	11.26^{a}	5.53^{f}	503.3^{cd}	2806.6^{e}	239.3^{b}
Rainwater irrigation	11.66^{c}	7.10^{f}	5.66^{f}	490^{c}	3156.6^{a}	259.3^{a}
Flood irrigation	23.63^{a}	8.46^{d}	9.76^{e}	510^{cd}	3126.6^{b}	219.3^{c}
Black plastic	11.36^{d}	10.56^{b}	11.83^{d}	543.3^{bd}	2770^{f}	180^{e}
Transparent plastic	11.03^{e}	9.06^{c}	44.20^{a}	626.67^{a}	2986.6^{c}	220^{c}
Dry-farming treatment	13.50^{b}	7.66^{e}	16.1^{b}	553^{b}	2993.3^{c}	219.3^{c}
Without culture	9.03^{f}	9.03^{c}	19.66^{c}	610^{a}	2846.6^{d}	200^{d}

within electrical diffusion double layer. This phenomenon causes reduction in the contact level of electrical diffusion double layer with soil solution where the roots are placed. Since potassium diffusion speed of electrical diffusion double layer to inside soil solution is a function of the above-said contact level, its usability is reduced for the plant. Increasing moisture of soil solution (place of roots) by irrigation may increase the above contact surface as well as, potassium diffusion speed toward roots. Increasing the moisture of soil solution by irrigation through reduction of soil mechanical resistance and increased growth in root may also provide more absorption of potassium with higher yield. By carrying out irrigation treatments, number of clusters was increased in unit area and yield. Thus, it is likely that soil moisture and irrigation is more important before clustering than the next stages after clustering. By conducting this study and with respect to coordination between nitrogen absorption by chaff and yield, it seems production of yields requires more supply of nitrogen , through irrigation and lifting of potassium limit.

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