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Testing the effect of AQUASORB and nitrogen rates on yield, nitrogen and water use efficiencies of wheat and hydro-physical properties of soil in Sudan Savanna, Nigeria

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Abstract

A study was conducted during the 2016/2017 dry season at the Irrigation Research Station, Kadawa, Kano State, Nigeria to investigate the effect of varying AQUASORB and nitrogen rates on the nitrogen and water use efficiencies, and yield of wheat (*Triticum aestivum L*) and hydro-physical properties of soil, to optimize both water and nutrient usage, which are critical limited in Sudan Savanna Ecological Zone of Nigeria. The experiment comprised of 16 treatment combinations: four levels of AQUASORB treatment A_1 (0 kg/ha), A_2 (50 kg/ha), A_3 (100 kg/ha), and A_4(150 kg/ha), and four levels of N- fertilizer F_1 (0 kg/ha), F_2 (50 kg/ha), F_3 (100 kg/ha) and F_4(150 kg/ha). This was laid in a randomized complete block design (RCBD) arrangement. A field representative soil sample was collected from each plot before and after harvest using cores and auger. Bulk density (BD), total porosity (TP), hydraulic conductivity (Ksat), and moisture content at various soil matric potentials, as well as crop coefficients were determined among others. Based on the result, pH (H_2O) and pH ($CaCl_2$) of the soil after the experiment (AE) were significantly higher than the soil before the experiment (BE) by 5.16 and 5.23 % respectively. Soil after the experiment (AE) was statistically greater than the BE in total nitrogen (TN) and OC by 30.57 % and 17.33 % respectively. Result for TP revealed that 150 kg/ha AQUASORB(A_4) recorded highest mean value which was greater than 100 kg/ha(A_3) by 6.15 %, 50 kg/ha (A_2) by 7.69 % and 0 kg/ha (A_1) by 5.12 %. On hydraulic conductivity (Ksat), the result depicted a significant variation and assumed a linear trend. The A_4 was higher than the control (A_1) by 10.01 %. Yield as affected by fertilizer rates ranged 995.5 – 1242.31 kg/ha and 150 kg/ha (F_4) outperformed 100 kg/ha(F_3) (by 0.4%); 50 kg/ha(F_2) (by 3.75 %); and 0 kg/ha(F_1) (by 5.44 %). Concerning nitrogen use efficiency(NUE) maximum mean value was recorded by F_4, significantly higher than the lowest (F_2) by 13.44 %. Both yield and NUE were highly significantly affected by the interaction.

Keywords: AQUASORB; Nitrogen; Water Use efficiencies; Hydro – Physical Properties

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1.0. Background of the Study

Scarcity of water is a global concern (WHO, 2008; Fereres and Soriano, 2007) which is being caused by population growth and erratic climatic trend. Daily demand for good quality water has continued to get intensified due to growing use by industries, agriculture, and residences(WHO, 2008). In particular, rainfall amount in the Savannah zone of Nigeria is grossly inadequate for optimum agricultural production, due to prolonged dry-spell, harsh temperature and sandy textured soil that favor evaporation and percolation loss (Chude *et al*., 2002; Abubakar *et al*., 2007). Under the condition of acute water supply, it is pertinent to bring onboard any possible means that minimizes water loss and improves water retention of Savanna's soil which translates to enhance water and nutrient use efficiencies/ productivities. Among strategies for conserving soil water and nutrients is the application of soil conditioners such as superabsorbent polymers (SAP)/ Polyacrylamide polymer (PAM) (AFLT, 2013). The most commercially marketed and accepted member of the SAP family is superabsorbent AQUASORB (Zohuriaan-Mehr *et al.,* 2010). Super absorbent polymer, such as AQUASORB, is one of the effective soil conditioners for enhancing infiltration, water, and nutrient retention (Entry and Sojka, 2003, and Bahr and Stieber, 1996). El-hady *et al.*(2002) suggest the application of AQUASORB to avert/forestall drought stress to crops. AQUASORB is a hydrophilic polymer that absorbs water or aqueous fluids. Kabiri *et al.,*(2011), advanced that, AQUASORB can absorb up to about 10 g of water per gram. (Buchholz and Graham, 1998) had found AQUASORB to imbibe up to 1,000 grams of water per gram.

Nitrogen is the most abundant element both in soil (79.2 %) and in the air (79.0 %) (Michael and Munn,2000). Atmospheric nitrogen (N_2) is only made available to crops through fixation by certain species of micro-organisms and lightning. However, it's perhaps the most limiting nutrient globally, especially, for tropical soil. This has led to high demand for inorganic N fertilizer in drylands, which add significantly to the production cost. Generally, the foliage of a healthy plant contains about 2.0–4.0% nitrogen (Brady and Weil, 2017). It is an integral component of amino acids, (the fundamental unit of all proteins) and enzymes, which control virtually all biological processes. Nucleic acids which control hereditary mechanism and chlorophyll that is necessary for photosynthesis are composed of nitrogen (Brady and Weil, 2017). Nitrogen stimulates root growth; development and the vigorousness of shoot, as well as facilitate uptake and use of other nutrients and carbohydrates (Miller and Donahue, 1992). Most crops have high sensitivity to added nitrogen; they exhibit deep green coloration of leaves, increased plumpness, and protein content of grains, roots, and tubers.

Conversely, nitrogen deficiency causes a drastic reduction in yield and total biomass. The most apparent symptoms are chlorosis (yellowish or pale green leaf colors) which first manifest in the older leaves, stunted growth, and thin and flimsy stems. It causes the crop to mature too early with a very low shoot – root weight ratio(Brady and Weil, 2017, Michael and Munn, 2000). On the other hand, the toxicity of nitrogen leads to several ecosystem imbalances and deleterious effects. When nitrogen is overly supplied, excessive vegetative growth occurs which predispose crop to lodge during windy and heavy downpour situation. Further, high nitrogen applications may delay plant maturity and increase crop susceptibility to pests and diseases and also scale down the quality of crop produce (Brady and Weil, 2017). Leaching of excess nitrogen from soil can cause surface and groundwater pollution, which may result in eutrophication(Idris *et al*., 2019; Saeed and Attaulah, 2013).

The severity of NO_3^- losses through leaching, denitrification, and volatilization processes (Arunah *et al.*, 2006; Miller and Donahue, 1992) monumentally affect nitrogen use efficiency. Leaching is often the most important (Chowdhary *et al*., 2004; Aulakh*et al*., 2000) especially in the irrigation production system and sandy textured soil, like that of the Savannah zone (Odunze, 2017; Ojanuga, 2003). Nitrogen losses via leaching may exceed 20 kg/ha, under normal field conditions and may run up to 50 – 80 kg/ha where heavy rainfall coincides with nitrogen fertilizer application (Miller and Donahue, 1992). The most important factors that contribute to the NO_3^- leaching is the rate of its use by plants; the amount of water; and soil permeability (Miller, and Donahue, 1992). Greater of N fertilizers use efficiency by crops, and retention of nitrate in soils, are two of the most critical indicators for reduced emissions of nitrogen oxides in tropical farming systems (Hickman et al., 2011). Nutrient use efficiency is the ratio of seed yield to the amount of nutrients in the above-ground parts of the plant (Rathke *et al*., 2006). Tittonell *et al*. (2007) described nutrient use efficiency as dry matter produced (Kg) by each Kg of nutrient uptake. Because, Nutrient use efficiency depends on potential crop yield, soil indigenous nutrient supply, amount of fertilizer application, and general land management practices (Dobermann *et al.,* 2002), NUE is, therefore, crop and location-specific. Research geared toward determining WUE and NUE for wheat crops in Sudan savanna, Nigeria becomes very significant.

2.0. Materials and methods

2.1 Experimental Site

The research was conducted at Irrigation Research Station of the Institute for Agricultural Research (IAR) in Kadawa, Kano state, Nigeria (Lat. 11° 38' N and long. 8° 25' E and altitude of 500m asl), Sudan Savanna Agro-Ecological zone of Nigeria. The rainfall pattern is unimodal with about 8 - 9 months dry season. The onset of rainfall is normally May-June while September is the wettest month in the area and has a temperature range of 27.8° C - 30.4°C.

2.2 Treatments and Experimental Design

The treatments consisted of four rates of AQUASORBA_1, A_2, A_3, and A_4(0 kg/ha, 40 kg/ha, 70 kg/ha and 100 kg/ha respectively) and four rates of N-fertilizer F_1, F_2, $F_3$and F_4 (0 kg/ha, 50 kg/ha, 100 kg/ha and 150 kg/ha respectively) which was laid out in a randomized complete block designt arrangement. The AQUASORB was assigned to the main plots, while N-Fertilizer treatment-- was imposed on subplots. The treatments were replicated five times.

2.3 Soil Sampling and Analysis

Disturbed and undisturbed soil samples were collected from the experimental site at 0 – 15 cm, 15 – 30 cm, using random sampling before planting and immediately after harvest using core and auger. Auger samples were bulked to form composite samples representing the entire field. Samples were also collected from each plot replicate to represent treatment soils. Standard procedures were followed to prepare and store the samples and later subjected to various laboratory analyses.

2.3.1 Laboratory Analysis

The following soil physical and chemical properties were determined: Particle Size Distribution by hydrometer method (Gee and Bauder, 1986), dry bulk density (*Pb*) by the core method (Black and Hartge, 1986), soil moisture retention, field capacity, and permanent wilting point using pressure plate extractors as described by (Klute, 1986), saturated hydraulic conductivity (Ksat) by constant head permeameter method (Klute and Dirksen, 1986), total porosity (TP) by using the mathematical expression of (Danielson and Sutherland, 1986) as; TP = 100 (1- ℓb/ℓp). Total nitrogen (TN) was determined by micro Kjeldahl digestion method (Bremner and Mulvaney, 1982), organic carbon (OC) by Walkley – Black wet oxidation method (Nelson and Sommers,1982), available phosphorous (Av. P) by Bray-1 method (Bray and Kurtz, 1945), exchangeable K by flame photometer (Black*,* 1965).

2.3.2 Field operation

The research field was cleared, ploughed, harrowed, leveled, and basins and water channels were constructed. The Gross plot size was 9m x 9m ($81m^2$), the net plot was 2m x 2m ($4m^2$), $1m^2$ lee-way was left between blocks, and $0.5m^2$ between plots. The seeds were treated with Apron star 42 WS (20% w/w thiamethoxam, 20% w/w metalaxyl-M, and 2 % w/w difenoconazole) at the rate of 4 kg of seed to 10 g before sowing. Seeds were sown by drilling at 20 cm intra row spacing at 3 cm depth and the rate of 100 kg ha^{-1}. Irrigations were done to the crop to allow for proper establishment, growth, and development. At three weeks to harvest irrigation was withheld to allow for proper and faster ripening. NPK 15: 15: 15and urea (46 % N) were used to supply varying N levels. Weeds were controlled by hoeing at 3, and 6 WAS. The crop was manually harvested at physiological maturity when the peduncles have turned brown using sickles. The crop was cut at ground level and sun-dried for 4 days. Threshing was achieved manually by beating out with sticks to expose the grain, which was winnowed in the open air with the help of wind current.

Reference evapotranspiration was estimated with the use of weather data obtained from the IAR meteorological station. Actual crop evapotranspiration was calculated from measured soil moisture content data using theta probe (Michael, 1978) as:

$$Eta = [\frac{M1-M2}{100}] Di \times Bdi$$

Equation 3

Where

Eta = actual crop evapotranspiration mm /day,

M1 = volumetric moisture content (cm^3/cm^3) at the first sampling (2 days after irrigation),

M2 = gravimetric moisture content (g/g) at the second sampling (7 days after irrigation)

Di = root zone depth

Bdi = bulk density of the soil

Theta probe was used to provide instantaneous soil volumetric moisture content throughout the crop seasons.

2.3.3 Water use efficiency

Water use efficiency (WUE) of wheat was calculated as the ratio of total yield (kg/ha) to total irrigation water applied, mathematically as

$$WUE = \frac{Y}{ETa}$$

Equation 5

Where,

Y = total yield (kg/ ha),

ETa = water use (mm/day)

Soil moisture was monitored in each plot a day after and on the day of application before the next irrigation to enable quantification of seasonal crop water use.

Equation 6

2.3.4 Yield response factors

Doorenbos and Kassam (1979) introduced the yield response factor (Ky) to describe the relationship between the ET deficit and yield reduction. In the approach, yield reductions and ET deficits are expressed in relative terms based on the maximum crop yield (YM), and corresponding ET at maximum yield. Yield response factor was computed for each of the AQUASORB and fertilizer rates. Thus, given below as:

$$-\frac{Ya}{YM} = Ky \times (1 - \frac{ETa}{ETM})$$

Where

Ya = actual yield (t/ha)

Ym = maximum yield (t/ha)

ETa = actual evapotranspiration (mm).

ETm = maximum evapotranspiration (mm)

Ky = yield response factor of wheat to deficit irrigation.

2.3.5 Nitrogen use efficiency (NUE)

The NUE, Kg of grain /kg of N applied) was determined using the following equation.

$$NUE = Y_N - \frac{YO}{FN} \text{ (kg of grain/kg of N applied)}$$

Equation 7

Where

YN = grain yield of N- Fertilized plot (kg/ha);

YO = grain yield of control plot (kg/ha) and

FN = amount of fertilized N (kg/ha applied)

2.4 Statistical analysis

Data obtained from all the measured parameters were subjected to the analysis of variance (ANOVA) using general linear model, SAS statistical package, and treatment means with significant differences at 5% probability level ($P < 0.05$) were separated using Turkey's Honesty Significant Difference (HSD) test. T-test was also carried out using Genstat Ed.14 to compare some selected parameters before and after the experiment.

3.0. Results and Discussion

3.1 Soil Physical and Chemical Properties of the Experimental Site Before and After the Experiment

Statistical output for pH (H_2O) and pH ($CaCl_2$) showed that the fertility and hydrophysical status of soil after the experiment (AE) had improved significantly than the soil before the experiment (BE). The former was greater than later by 5.16 % and 5.23 % respectively. This may be connected with a concentration of retained primary cation by AQUASORB polymer, which facilitates its dominance in the exchange sites of the soil. As observed, soil after the experiment (AE) was statistically greater than BE in total nitrogen (TN) and organic carbon (OC)by 30.57 % and 17.33 % respectively. The rapid increase of TN and OC may be because organic matter residues met on the field was ploughed into the soil during land preparation practices, which get decomposed, mineralized through the production period.

Further, because the experiment was carried out during the dry season, the flash release of OC and TN upon irrigation might have occurred. Both potassium (K) and calcium (C) exchangeable bases behaved similarly, in which case they increased significantly after the experiment, which suggested the ability of AQUASORB treatment to retain more nutrients in the soil. Total porosity was observed to improve in a significant way by 9.0 % in AE soil. Amendment with the AQUASORB polymer had aided in the expansion of soil porosity, which suggests more water intake, and optimum aeration tendencies. On the other hand, bulk density (BD) and available phosphorus (Av. P) were highest in BE soil, the former (BD) which was higher by 8.48 % might have resulted due to surface caking from constant solar heating, while the later, (Av. P) which was higher by 7.16 %in BE soil may be due to inactivity/ dormancy of mycorrizobia that could be able to solubilize the P and enhance its uptake by crops due to dryness.

The result for TP showed significant variation across the various AQUASORB rates. The A_4 recorded the highest mean value, which was more significant than A_3 by 6.15 %, A_2 by 7.69 %, and A_1 by 5.12 %. On hydraulic conductivity Ksat, the result depicted a significant variation and assumed a linear trend, meaning it increased with an increase in AQUASORB rate. The A_4 was higher than the control (A_1) by 10.01 %. Naturally, the AQUASORBcan mix thoroughly and effectively with the soil to cause an increase in total porosity as observed, thereby affecting the hydraulic gradient to cause higher Ksat.

Table 3 presented the moisture content at various tensions. At 0 kpa, soil treated with A_4 AQUASORB was higher over A_3, A_2, and $A_1$by 5.1 %, 10.71 %, and 10.71 % respectively. A similar observation was made concerning moisture content at 10 kPa. This may be expected as AQUASORB reduces the amount of water lost by deep percolation. Sivapalan (2001), reported that the amount of water retained by sandy soil under the pressure of 0.03 MPa increased significantly with the addition of 0.03% and 0.07 % SAP to 23 and 95 percent, respectively. Ghaiour, (2000) had reported it increased soil moisture by 2 and 4 times with the addition of 4 and 8g kg^1 super absorbent polymer in a loamy soil respectively.

The A_2 AQUASORB level does not differ with the control (A_1) concerning moisture status across all the matric potentials determined. This could be attributed to a meager difference between the two AQUASORB rates, which could not impact any pronounced effect for short-term research. Similarly, A_3 and A_4 were statistically not different except at 0 kPa, which implies that the A_3 AQUASORB rate could suffice for economic production. At high-pressure potential, up to the wilting point stage (1500 kPa), no significant difference was observed across the AQUASORB levels. This could be ascribed to harsh environmental factors, particularly soil temperature, which may impair the optimal functions of AQUASORB. All the variables presented in table 2 and 3 did not express significant variation with varying fertilizer level. The result is not uncommon as fertilizer does not usually affect the hydro-physical properties of soils. AQUASORB – fertilizer interaction significantly changed TP and Ksat at 0.01 and 0.05 levels of significance, respectively.

Table 4 presents the yield response to AQUASORB and

fertilizer level factors. The yield (kg/ha) ranged from1037.91 to 1239.61kg/ha for AQUASORB. Plots treated with A_4 recorded maximum mean value which superseded A_3, A_2, and A_1 by 1.192 %, 3.11 %, and 4.42 %. Result for nitrogen use efficiency (NUE) also depicted a trend: A1 < A2<A3< A4 and it ranges 0.00 – 3.45 kg/kg. More available water content brought about by the addition of AQUASORB highest rates may have enhanced water and nutrient retention and absorption by the wheat crop, which translated to more NUE and yield produced. Fertilizer difference similarly affected both the yield and NUE parameters. The yield ranged 995.5 – 1242.31 kg/ha and F_4 outperformed F_3 (by 0.4%), F_2 (by 3.75 %) and F_1 (by 5.44 %). Concerning NUE, the maximum mean value was obtained by F_4, significantly higher than the lowest mean value(F_2)by 13.44 %. Both yield and NUE were highly significantly affected by the interaction. The addition of nitrogen fertilizer in soils of the savannahs, which has a very poor nutrient base as indicated by the soil before the experiment (Table 1) is likely to cause a better response which led to higher yield results. This is contrary to the findings by Somarin *et al.,* (2010) who reported that increased N level reduced NUE. Scharf, and Lory,(2002) Also, reported that N fertilization increases NUE, but the highest N level reduced NUE.

The water use efficiency (WUE) index was statistically similar for A_4 and A_3, likewise A_2 and A_4. And WUE ranged from 6.28 kg/m^3 – 6.99 kg/m^3. The A_3 carries superscript 'a' having obtained the highest mean. The effect that AQUASORB exerted on nutrient storage, total porosity, and reduced bulk density may have affected root development which resulted in increased water uptake and biomass growth and production. This conforms with the finding by Wu *et al.* (2008)who reported that with the use of 0.03 % and 0.07% SAP, water use efficiency for plants increases by 12% and 19 %, respectively.

4.0. Conclusion

From the outcome of the experiment, it is evident that most of the parameters tested were significantly affected by the AQUASORB amendment. Total porosity, hydraulic conductivity, bulk density, grain yield, nutrient, and water use efficiencies were all improved by A_4 (150 kg/ha) and A_3(100 kg/ha). However, the addition of 50 kg/ha did not improve NUE, WUE, and yield and hydro-physical properties determined, in other word, the amendment of soil with (A_2) 50 kg/ha was not better than (A_1) 0 kg/ha AQUASORB. Although based on the result obtained, the performance of A_4 outweighed all the other levels of the AQUASORB treatment. A categorical conclusion cannot be made until a series of validation trials are conducted. It was therefore recommended that more research be carried-out on AQUASORB rates until homogenous data is generated that could be used to standardize the recommended application rate. As presented in the results, it could be concluded that most of the physical and hydraulic properties determined were not influenced by fertilizer treatment. However, F_3 and F_4had improved nitrogen and water use efficiencies. Because, increasing fertilizer rate from 100 kg/ha – 150 kg/ha (F_3 – F_4) does not bring about a significant difference in three out of the four parameters tested, therefore the application of F_3 was recommended for sustainability, profitability, and environmental safety. Generally, OC, TN, Exch. bases had increased after the experiment

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Table 1 Effect of AQUASORB and N-Fertilizer on physical and chemical properties of the soil in the experimental site

Soil Parameter	**BP 0 – 15**	**AP 0 -15**	**SE**	**BP 15– 30**	**AP 15 - 30**	**SE**
pH (H_2O)	5.8b	6.43a	0.0048	6.80	6.81ns	0.0054
pH ($CaCl_2$)	4.89b	5.43a	0.0071	5.20	5.22ns	0.0033
Organic Carbon (g/kg)	0.537b	1.01a	0.0003	0.357a	0.257b	0.00021
Total Nitrogen (g/kg)	0.062b	0.088a	0.0001	0.0441	0.0411ns	0.00011
Av.P (mg/kg)	7.79a	6.75b	0.0999	4.99a	4.01b	0.0131
Exch. K (Cmol/100g)	0.19b	0.38a	0.0005	0.16b	0.21a	0.0007
Exch. Ca (Cmol/100g)	0.222b	0.302a	0.0022	0.179	0.183ns	0.0012
BD (Mg/m^3)	1.47a	1.24b	0.0046	1.57a	1.40b	0.00099
Sand (%)	85.5	80.5ns	2.755	83.00	78.8ns	2.503
Silt (%)	10.5b	14.0a	0.888	11.00a	15.0a	0.987
Clay (%)	4.0b	5.5a	0.0532	6.00	6.20 ns	0.0555
Textural Class	Loamy sand	Loamy sand		Loamy sand	Loamy sand	
Total Porosity (%)	37.4b	44.99a	1.198	40.00b	45.61a	1.333

Means with different letters across the row are significantly different at a 5 % level of significance. BD = bulk density

Table 2 Effect of AQUASORB and fertilizer levels on selected soil physical properties

Factor Levels / interaction	BD (g/cm^3)	TP (%)	K sat (cm /sec)
AQUASORB Level (A) (kg/ha)			
A1	1.56a	48.0b	2.71b
A2	1.44b	43.0c	3.02b
A3	1.21c	46.0b	3.79a
A4	1.21c	58.0a	4.07a
SE ±	0.097	0.10	0.334
Fertilizer Level (F) (kg/ha)			
F1	1.52	47.0	2.79
F2	1.49	49.0	2.72
F3	1.51	48.0	2.80
F4	1.56ns	48.0ns	2.31ns
SE ±	0.897	0.10	0.334
Interactions			
A x F	NS	**	*

BD, soil bulk density; TP, total porosity; K sat, saturated hydraulic conductivity A1= 0 kg/ha; A2 =50 kg/ha; A3 =100 kg/ha; A4 = 150 kg/ha and F1 = 0 kg/ha; F2 = 50 kg/ha; F3 100 kg/ha; F4= 150 kg/ha SE standard error, NS = not significant * = significant at $p\leq 0.05$ ** = significant at $p\leq 0.01$

Table 3 Effects of AQUASORB and Fertilizer on Soil Water Content

Factor Levels/interaction	Water content (cm^3/cm^3) at various matric potentials (Kpa)						
	0	10	33	10	500	1000	1500
AQUASORB Levels (A)							
A1	0.41c	0.26b	0.21b	0.22	0.17	0.12	0.03
A2	0.41c	0.25b	0.22b	0.24	0.19	0.15	0.04
A3	0.52b	0.37a	0.28a	0.22	0.17	0.14	0.05
A4	0.62a	0.37a	0.28a	0.24ns	0.19ns	0.14ns	0.05ns
SE ±	0.011	0.011	0.009	0.009	0.009	0.010	0.002
Fertilizer Levels (F)							
F1	0.41	0.32	0.27	0.21	0.17	0.13b	0.05
F2	0.41	0.34	0.27	0.24	0.19	0.15ab	0.03
F3	0.40	0.33	0.29	0.22	0.18	0.14ab	0.04
F4	0.41ns	0.34ns	0.28ns	0.24ns	0.19ns	0.18a	0.03ns
SE ±	0.011	0.011	0.009	0.009	0.009	0.002	0.002
Interactions							
A x F	*	*	NS	NS	NS	NS	NS

A_1 =0 kg/ha, A_2= 50 kg/ha, A_3=100 kg/ha, A_4= 150 kg/ha, and F_1=0 kg/ha, F_2=50 kg/ha, F_3=100 kg/ha, F_4= 150 kg/ha.Means with the same letter within each factor are not significantly different at 5% level of probability using Turkey's Honesty significant Difference (HSD) test.

Table 4 Means of wheat yield and Nitrogen use efficiency as influenced by AQUASORB and fertilizer Levels.

Factor Levels/ interaction	Yield (Kg/ha)	NUE (Kg yield $Kg^{-1}N$)
AQUASORB Level (A)		
A_1	1037.91^c	0.00d
A_2	1097.49^c	2.04^c
A_3	1185.35^b	2.974^b
A_4	1239.61^a	3.45^a
SE ±	158.249	0.018
Fertilizer Level (F)		
F_1	995.5^d	0.00d
F_2	1072.7^c	1.544^c
F_3	1223.9^b	2.284^a
F_4	1242.31^a	1.692^b
SE ±	158.249	0.018
Interactions		
A x F	**	**

A_1 =0 kg/ha, A_2= 50 kg/ha, A_3=100 kg/ha, A_4= 150 kg/ha, and F_1=0 kg/ha, F_2=50 kg/ha, F_3=100 kg/ha, F_4= 150 kg/ha. Means with the same letter within each factor are not significantly different at 5% level of probability using Turkey's Honesty significant Difference (HSD) test. SE = standard error NS = not significant * = significant at $p \leq 0.05$

Table 5 Means of seasonal water applied, seasonal actual evapotranspiration and irrigation water use efficiency of wheat

Factor levels/ Interaction	SWA (mm)	SETa (mm)	WUE (Kg/m^3)
AQUASORB Levels(A)			
A_1	190.7	306.3	6.28^c
A_2	190.7	357.1	6.63^b
A_3	190.7	385.7	6.99^a
A_4	190.7	409.2	6.78ab
Fertilizer Levels(F)			
F_1	190.7	374.5	6.35^b
F_2	190.7	366.1	6.43^b
F_3	190.7	357.2	7.09^a
F_4	190.7	360.4	7.11^a
Interactions			
A X F			*

SWA, seasonal water applied; SETa, seasonal actual evapotranspiration and IWUE, irrigation water use efficiency, A1(O)kg/ha; A2(50)kg/ha; A3 (100)kg/ha; A4(150)kg/ha; means with the same letter in a column are not significantly different at 5% level of probability using Tukey's Honesty Significant Difference (HSD) test. SE = standard error NS = not significant * = significant at $p \leq 0.05$ ** = significant at $p \leq 0.01$

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