Effect of Different Super-Absorbent Polymer (SAP) Rates on Vegetative Growth and Forage Characteristics of Some Cereal Crops

Ibrahim Salim Ismael[1] Fathi Abdulkareem Omer[2]

[1]Department of Field Crops, Collage of Agricultural Engineering Sciences, University of Duhok, Iraq.

[2]Department of Field Crops, Collage of Agricultural Engineering Sciences, University of Duhok, Duhok, Iraq.

Ibrahim.ismael@uod.ac , Fathi.omer@uod.ac

Abstract:

The experiment was undertaken to estimate the effect of four rates (0, 15, 30, 45) kg/donum^{-1} of super-absorbent polymer (SAP) on vegetative traits, fresh and dry herbage yield kg/ha^{-1}, of three cereals forage crops include; barley, oat and triticale. The study was located in the University of Duhok, Collage of Agricultural Engineering Sciences, farm of field crops department. The results showed that, the most of studied traits demonstrated no significantly affected by SAP, except the flag leaf area at SAP rate15 kg/donum^{-1} and fresh herbage yield at SAP rate 30 kg/dunam^{-1}, which revealed significantly increased and gave the best records comparing with control and other rates. However, the rest of vegetative traits indicated that no significantly affected by SAP rates. The study was done under suitable temperatures and high level of precipitation throughout the growing season as showed in table (1). This study showed that, the different rates of SAP had limit influences on the most of vegetative traits of those forage cereal crops. Therefore, SAP application appears to be more suitable and functionally effective under arid and semiarid conditions than in regions where rainfall is sufficient during the growing season.

Keywords: SAP, Vegetative, Barley, Triticale, Oat and Herbage Yield.

الخلاصة:

أُجريت هذه التجربة لتقييم تأثير أربعة مستويات من البوليمر فائق الامتصاص للماء(SAP) ، وهي 0، 15، 30 و45 كغم دونم$^{-1}$، في بعض الصفات الخضرية ومحصول العلف الأخضر والجاف (كغم هكتار$^{-1}$) لثلاثة من محاصيل الحبوب العلفية، وهي الشعير والشوفان والتريتيكال. نُفذت الدراسة في مزرعة قسم المحاصيل الحقلية، كلية علوم الهندسة الزراعية، جامعة دهوك. أظهرت النتائج أن معظم الصفات المدروسة لم تتأثر معنوياً بإضافة البوليمر فائق الامتصاص(SAP) ، باستثناء مساحة ورقة العلم عند مستوى الإضافة 15 كغم دونم$^{-1}$، ومحصول العلف الأخضر عند مستوى 30 كغم دونم$^{-1}$، إذ أظهرت كلتا الصفتين زيادة معنوية وسجلتا أعلى القيم مقارنةً بمعاملة المقارنة (0 كغم دونم$^{-1}$) وباقي مستويات الإضافة. في المقابل، لم تُظهر بقية الصفات الخضرية فروقاً معنوية استجابةً لمستويات SAP المختلفة. أُجريت الدراسة في ظروف اتسمت بدرجات حرارة ملائمة ومستويات مرتفعة من الهطول المطري خلال موسم النمو، كما هو موضح في الجدول (1). وتشير نتائج الدراسة إلى أن المستويات المختلفة من SAP كان لها تأثير محدود في معظم الصفات الخضرية لمحاصيل الحبوب العلفية المدروسة. وعليه، يبدو أن استخدام SAP قد يكون أكثر ملاءمة وفاعلية تحت الظروف الجافة وشبه الجافة مقارنةً بالمناطق التي تتلقى كميات كافية من الأمطار خلال موسم النمو..

كلمات المستخدمة: الشعير, الشوفان, التريتيكال, SAP , حاصل العلف.

ISSN 2072-3857

Introduction:

Barley (*Hordeum vulgare* L.) is considered one of the most broadly yielded cereal crops in the world, with, more than 145 million tons produced in 2023 [1]. Traditionally, the production of this crop has been globally imperative, and it considered as the fourth most-yielded cereal after wheat, rice, and maize. The most varieties of barley are sown in Iraqi Kurdistan Region under participation conditions, which often lead to fluctuation in the yield and that depend on amount of rain and its distribution, and also the least availability of enhanced and high-quality varieties and finally the system of fertilizers application. This is accomplished by examine most of local varieties, evaluation their condition for drought tolerance, and determine the most original varieties that suitable for our zone conditions especially for early harvesting [2].

[3] identified that triticale (X *Triticosecale Wittmack*) was measured as a supernumerary to wheat crop as a source of food. However, since the year of 1970s there had been improved attention in cultivating of (triticale) as a preserved forage or grassland and presently in yield of bio-energy (The yield of both types; spring and winter) has impacted how this crop is utilized? The growth of triticale is improved steadily for grazing of livestock, silage as full-plant, hay yield, and production of grain for forage uses. The most varieties of triticale own prominent awns; otherwise there are many varieties in the world with low awns [4]. Whole of this varieties produce more appropriate for wrapping grazing and fresh forage or fodder [5].

Oat, *Avena sativa* L. is a forage crop that usually used as forage in winter season, and they are usually sown mostly to feed the livestock's as a reason of its rich amount of fermentable carbohydrates [2]. Oats are measured as one of the major dependable winter cereal forage and globally its sown for seed yield for animal feed, bedding litter for livestock stable and also seed yield for human food manufacture. It has moist, dulcet and nutritious fresh yield. The herbage of oat is gaining high yield. This prices crop is considered as an addition for the high content of dry matter and value when mixed with other forage crops such as fodder of Lucerne and clover [6].

The deficiency of precipitation in the last years leads to the researchers to look for a suitable solution and improved techniques to overwhelmed this problem. The SAP (super-Absorbent Polymer) is considered as a substance of polymer that has insecurely cross-connected with a limited width-wise connection. This lets it to work as absorption and storage for water and that weighing tens of times more than the dry weight polymer [7, 8]. The chemical characteristics of SAP, such as its structure, molecular weight, and conditions of hydrogel formation, govern its performance. Because of its ability to retain water, SAP lowers soil hydraulic conductivity in field applications [9]. According to certain research, swelling SAP decreased the soil's biggest pores [10]. Furthermore, the contact between soil and SAP was increased to a superior degree by the mixing ratio of SAP and soil, and the influence of SAP's swell ability. When SAP was applied and added to the field soil, the saturated and content of residual water, capacity of water-holding, and accessible water content were increased [11, 9]. Additionally, leakage and subsequent losses resulting from deep filtration were decreased [10]. The aim of this research is to study the impact of super-absorbent polymer on

ISSN 2072-3857

vegetative growth and forage characteristics of some cereal forage crops (barley, triticale and oat). Also, to identify the most effective rate of SAP for enhancing the growing performance of the mentioned crops.

Materials and methods

Experimental site:

This study was carried out in the winter of growing season 2025-2026 at the Field Crop Department farm, Agricultural Engineering Sciences College / University of Duhok; located between latitudes 36.84°N and longitudes 43.01°E, 583 meters altitude. To study the influence of super absorbent polymer (SAP) on some early vegetative characters, fresh herbage and dry herbage yield kg/ ha of the forage crops: barley, *Hordeum distichum* L., oat, *Avena sativa* L and triticale, X *Triticosecale Wittmack.*

SAP is hydrogels substance, granules size with approximately (0.15 to 0.85 mm) that used to improve water retention and reduce irrigation frequency. It consists of synthetic polyacrylate-based which composed of (C3H 3NaO2) n / and (n) represents approximately ≈700 to 2,000 (typical commercial super-absorbent polymer) according to [39]. It is applied during the seed sowing with soil 3-5 cm in soil same as seeds depth according to [34].

Land preparation:

The land was plowed during November 2025 after effective rain to minimize the weeds by (Tyne), cultivator and levelling with dual achievement harrow disc before sowing. Rain, atmospheric relative humidity percentage, and maximum and minimum temperatures of the field farm location were registered daily by metrological station in Duhok city, by using thermo-hygrograph table (1). Soil properties of the land were also recorded according to [12] table (2).

The experimental design:

The research was spilt plot design in "Randomized Complete Block Design" (RCBD) as factorial preparation, which consist of three factors (barley, triticale and oat) and three treatment of (SAP) levels with three replications. Crops (barley, triticale and oat) allocated as the main plot, while the SAP (Super-Absorbent Polymer) levels (0, 15, 30 and 45) kilograms per donum were used as sub-plot. The crops seeds sowing was done in the 5th of November 2025 at rate of seeding target 250 plants per m^2 [2]. Table (3).

ISSN 2072-3857

Table (1) The monthly averages of rainfall (mm), relative humidity (%) of the air, and max and min temperatures (°C) from November 2025 to the end of June 2026 during the growth season.

2025-2026 Months	Average relative humidity %	Temperature, °C		Precipitation (mm)
		Max.	Min.	
November	46.0	24.1	11.0	86.0
December	73.0	14.5	6.7	129.8
January	73.0	10.9	2.8	130.5
February	67.0	15.0	7.4	72.4
March	73.0	15.5	7.6	356.8
April	71.0	20.9	11.3	175.8
May	53.0	27.9	15.8	29.8
June	30.0	37.7	23.1	0.0
Total				981.1

Table (2) Soil properties of the experimental land

Parameters	Units	Experimental land
Soil pH	–	7.75
Electrical Conductivity (EC)	dS m^{-1}	0.31
Total Nitrogen (N)	mg/kg^{-1}	74
Available Phosphorus (P)	mg/kg^{-1}	4.43
Potassium (K)	mg/kg^{-1}	15.66
Organic Matter (OM)	%	1.48
$CaCO_3$	%	18.52
Cation Exchange Capacity (CEC)	cmolc/kg	27.94
Clay (C)	%	48.80
Silt (Si)	%	45.43
Sand (S)	%	5.77
Soil Texture	–	Silty Clay

ISSN 2072-3857

Table (3): Adjusted target seeding rates

Crops	Targ/seed rate/m^2	TSW(g)	Ger. %	Est/ 80%	Kg/ha-^{1}	g.m^2	g/row
Barley	250	30.7	93	80%	10315.8	10.31	5.2
Triticale	250	46.2	92	80%	15865.3	15.86	8
Oat	250	31.1	92	80%	10563.8	10.56	5.3

Seeds Source:

Seeds source of triticale (variety: Admiral) were supplied by the Company of Agriculture Research Development/ (ARD), city of Erbil; and six-rows barley (variety: Nomar) was supplied by Department of Field Crops, Baghdad University and oat (variety: Anatolia) provided by the Department of Field Crops, Baghdad University.

The grains were well purified from whole unwanted materials, chaffs and inert impurities to make sure obtain (100 %) high quality of seeds, then the seeds were sieved with aperture sieve (2 mm) to get seeds with uniform size. According to [40] Rules, as showed by [13], the standard germination test was carried out.

Four replicates of 100 seeds were germinated at 22 oC, for seven, eight and ten days, for triticale, barley and oat, respectively in a germinator, finally, the normal germination percentages test were recorded. The weight of thousand seeds (g) was taken as well.

The following formula was utilized for rates sowing seeds at the establishment value (80%) which applied according to [2, 13, 14]. The information of adjusted seeding target was cleared in (table 3).

$$\text{Seeding rate (kg/ha}^{-1}) = \frac{\text{target plants per m2 X1000 seeds wt g X100}}{\text{germination x establishment 80\%}},$$

then it converted to kg per donum. Seeds (g) per row were showed below according [13]:

Recorded Measurements

Plant height (cm): The tillers height of main ten plant were recorded and that was done from the soil surface till the end of spike or panicle include awns at pre-harvesting or full stage of ripening according to growth stage (BBCH stage, 59) end of heading, (spike or panicle) with fully developed, [15].

Total and productive tillers number per one-meter length: It was estimated after completed stage of tillering, at stage of growth (BBCH, 59) end of heading, (spike or panicle) with fully developed, [15]. The total number of tillers were measured, then number of fertile tillers for one (m) row length and then converted to one (m^2) according to equation [16].

$$\text{Plants.m}^2 = \frac{\text{average plant number.m}-1\text{ row X100}}{\text{row spacing (cm)}}$$

Leaf/stem ratio: To determine the leaf to stem ratio, a freshly harvested plant was selected at random, the leaves were removed from its stems, and its weight was recorded. According to the BBCH Monograph, [15], the trait was tested at the growth stage

ISSN 2072-3857

(BBCH, 59) last stage of of heading (spike, or panicle) fully developed.

Spike biomass (g): A fresh spike or panicle were removed and weighed per plant according to [17]. The trait was estimated at stage of growth (BBCH stage, 59) last stage of heading (spike or panicle) fully developed according to [15].

Flag leaf area (cm^2): Ten random flag leaf length and breadth were recorded from the one of the middle rows for each plot. The length multiplied by width and (0.75) according to [19], to estimate the flag leaf area by applying this formula:

Flag leaf area = Length (L) x Breadth (B)x 0.75

Fresh herbage yield kg/ha^{-1}: One meter of middle row plants was harvested in 5th of April 2025, at growth stage (BBCH, 59), end of heading of (spike or panicle), fully emerged according to BBCH Monograph, [15]. The plant cut at two (cm) above soil surface then weighed in (g) after that converted to kg/ha^{-1} according to modified formula [18]:

Average biological yield (kg/ha^{-1}) $\frac{\text{biological yield,kg}}{\text{area harvested m2}}$= x10000

Dry herbage yield in kg/ha^{-1}: The plant that harvested for fresh herbage yield was left for 20 days to air-dry, then weight was taken as dry in (g) and then converted to kg/ha^{-1} according to the above-revealed formula.

Results and Discussion:

The result in table (4) indicated that there were significant differences among the crops, triticale showed the highest value in terms of the average height of plant (cm) (132.32) while barley gave the lowest value with (94.62). In terms of SAP rates effect, there were no significant differences among the records. The result similar to [21] who found that, the application of hydrogel polymer showed no effect on the rate and power of germination of barley under increasing the value of ECi conditions. With high level of precipitation during the growing season, barley, triticale, and oat fields likely had sufficient natural moisture, so that the superabsorbent polymer (SAP) showed no observed influence on the plant height measurements. The SAP substance are intended to absorb and store water through the drought condition to be utilized slowly by plants, however, with heavy rainfall and excessive of humidity, the function of SAP becomes unnecessary [11]. In contract, the study of [22] mentioned another aspect and claimed that there was positive impact of using SAP on the vegetative characteristics such as of the plant height.

In terms of interaction between crops and SAP rates, the results indicated that there were significantly differences, which triticale showed heights records at rate of 45 kg/$dunam^{-1}$ and obtained (134.67) while, the least value recorded for barley.

ISSN 2072-3857

The results in table (5) showed that there were significant differences among crops, which oat recorded the highest value comparing with other crops and gave (66.46) while the lowest values were (29.40) and (31.47) for barley and triticale respectively.

increasing the plant shoot and root comparing with yield and yield component.

The interaction between the crops and SAP levels showed that there were significantly differences among the values and the highest one registered for oat with 15 kg/dunam^{-1}

Table (4) Effect of SAP Rates on Average Plant Height (Cm) of Barley, Triticale and Oat

Crops	Rates of SAP				
	0 kg/d	15 kg/d	30 kg/d	45 kg/d	Mean of Crops
Barley	90.40 e	102.4 de	90.27 e	98.0 e	94.62 c
Triticale	130.07 abc	130.60 abc	131.80 ab	134.67 a	132.32 a
Oat	120.53 bcd	128.0 abc	130.27 abc	129.07 abc	126.97 b
Mean of SAP rates	114.2 a	119.53 a	117.84 a	120.34 a	

Means followed by the same letter within each factor or interaction are not significantly different at the 0.05 probability level according to Duncan's multiple range test [20].

Table (5) Effect of SAP Rates on Average Flag Leaf Area (Cm) Of Barley, Triticale and Oat

Crops	Rates of SAP				Mean of Crops
	0 kg/d	15 kg/d	30 kg/d	45 kg/d	
Barley	24.23 d	32.71 c	31.41 c	29.25 c	29.40 b
Triticale	24.23 c	37.11 c	31.21 c	30.99 c	31.47 b
oat	59.76 b	76.51 a	60.29 b	69.36 ab	66.46 a
Mean of SAP rates	36.80 b	48.78 a	40.98 b	43.20 ab	

Means followed by the same letter within each factor or interaction are not significantly different at the 0.05 probability level according to Duncan's multiple range test [20].

The result also revealed that there were significant differences among the effect of SAP levels on the average flag leaf area (cm) which the rate of 15 kg/dunam^{-1} was more effective on increasing the values comparing with the others, however, there was no significant differences between rates of 30 and 45kg/dunam^{-1} values. This result was supported by those of [22] who found that 30 kg/ha^{-1} showed the highest records of flag leaf area in wheat. The results were also in harmony with those of [23] who mentioned that SAP play important role in

SAP rate, which gave (76.51) while the lowest value was for control of barley (24.23).

The result in table (6) indicated that there were significant differences among the crops in terms of total number of tillers per m^2, barley outcome the superior number of tillers comparing with triticale which gave the inferior number. In addition, this table indicated that there was no significant effect of SAP rates on total number of tillers of used crops. Similar study was done on wheat

ISSN 2072-3857

in Poland, also noticed that there was no significant effect of SAP rates on the tillers and ear number [24]. This study was done under high rainfall condition during the growing season as showed table (1) and that might be the reason which impact on the activity of SAP in the field. Furthermore, [25] recommended that SAP should not be utilized in zone with high precipitation level while only for semiarid area. On the other hand, [22, 26] showed different aspects, who reported that adding SAP at sufficient rates in the soil leads to improve the biomass yield including tillers number of plants.

For the interaction between crops and SAP levels, the result revealed that there was fluctuation in significances among the values. Barley with control and treated with SAP rates owned the preferences to produce the best values comparing triticale.

The results in table (7) revealed that there were significant differences among the crops in terms of number of productive tillers per m^2, and triticale show the lowest records comparing with barley and oat with the highest outcomes.

For the effect of SAP rates, the table demonstrated that there was no significant effect of SAP rates on the values of productive or fertile tillers. The result in agreement with [24] who found that there was no significant effect of SAP on number of tillers and ear. However, [22, 27], completely disagreed, who found that the number of fertile tillers and ears increased by using SAP at low, medium and high rates. Since sufficient soil moisture may have met the crop's water requirements, the additional effect of SAP might have been limited or less pronounced under the prevailing environmental conditions this aspect agreed with [34]. Furthermore, [35] study claimed that cereals and soils of low water-holding capacity are highly reactive to SAP than water saturated soil.

Table (6) Effect of SAP Rates on Total Number of Tillers Per m^2 of Barley, Triticale & Oat

Crops	Rates of SAP				Mean of Crops
	0kg/d	15 kg/d	30 kg/d	45 kg/d	
Barley	13.27 a	10.27 abc	12.60 ab	12.07 abc	12.05 a
Triticale	5.73 d	7.40 cd	7.73 cd	7.33 cd	7.05 c
oat	10.33 abc	12.87 ab	11.60 abc	8.93 bcd	10.93 b
Mean of SAP rates	9.87 a	10.18 a	10.64 a	9.44 a	

Means followed by the same letter within each factor or interaction are not significantly different at the 0.05 probability level according to Duncan's multiple range test [20].

Table (7) Effect of SAP Rates on Productive Tillers Per m^2 of Barley, Triticale & Oat

Crops	Rates of SAP				Mean of Crops
	0kg/d	15 kg/d	30 kg/d	45 kg/d	
Barley	12.47 a	10.00 abc	12.47 a	11.33 abc	11.57 a
Triticale	5.13 e	7.27 cde	7.67 cde	7.13 cde	6.80 c
Oat	9.47 bcd	12.13 ab	11.07 abc	8.67 bcd	10.33 b
Mean of SAP rates	9.02 a	9.80 a	10.40 a	9.04 a	

Means followed by the same letter within each factor or interaction are not significantly different at the 0.05 probability level according to Duncan's multiple range test [20].

ISSN 2072-3857

In terms of interaction between the crops and SAP rates, the results show that there were significant differences among the records. Barley yielded the highest productive tillers number while triticale showed the lowest number.

The result in table (8) indicated that there were significant differences between of both crops (barley and triticale) with oat in terms of the leaf to stem ratio. Barley and triticale recorded the highest values (37.98 % and 35.55 %) respectively, comparing with the lowest value for oat (31.92%).
The abundant water supply may have reduced moisture stress and minimized the potential advantage of SAP in conserving additional soil water, this is supported by [28] who reported that increase the level of rainfall and soil water lead to keep the soil wetter longer than the normal situation and finally tend to plant lodging and that might be negatively influence the leaf area. Same as our results, many plots showed lodging of the plant in current study field at early growing stages. Furthermore, the finding of [29] also revealed that increase the water absorption by SAP in the soil leads to leaching in root zone and that possibly effect on shoot accumulation in the plant. On the other hand, [30] found different results when applied of SAP in maize field and the finding indicated that SAP significantly effect on leave development and that why his study recommended to utilize SAP in the field.
Regarding the second order interaction, there were significant differences among the records. Barley show the highest value whereas oat gave the lowest value.

The result of table (9) demonstrated that there were no significantly differences among the measurements regarding to spike or panicle weight (g). in addition, the result found that there were no significantly influences of the rates of SAP on the spike or panicle weight (g). These results completely contrast to many studies which found that SAP play important role in improving the weight of spike in the cereal crops such as wheat [31]. Also, [24] revealed different aspects, and mentioned that, SAP play remarkable role in ear development of wheat. However, high and intense rainfall during the growing season can change soil moisture status, nutrient availability, disease pressure, and plant morphology, thereby influencing measured growth and yield components in cereal crops, this aspect supported by [41] findings as well. The study of [34] also found that SAP effects are stronger when the amount of water is limited.

Table (8) Effect of SAP on Average Leaf/Stem Ratio of Barley, Triticale & Oat

Crops	Rates of SAP				Mean of Crops
	0 kg/d	5 kg/d1	30 kg/d	45 kg/d	
Barley	38.93 a	37.30 abc	38.10 ab	37.60 abc	37.98 a
Triticale	38.50 ab	32.00 bcd	36.63 abcd	35.10 abcd	35.55 a
oat	33.10 cd	30.50 d	33.10 abcd	31.00 cd	31.92 b
Mean of SAP rates	36.84 a	33.26 a	35.94 a	34.56 a	

Means followed by the same letter within each factor or interaction are not significantly different at the 0.05 probability level according to Duncan's multiple range test [20].

ISSN 2072-3857

Table (9) Effect of SAP Rates on Spike or Panicle Weight/Plant of Barley, Triticale & Oat

Crops	Rates of SAP				Mean of Crops
	0 kg/d	15 kg/d	30 kg/d	45 kg/d	
Barley	26.30 c	37.67 abc	43.03 ab	36.30 ab	35.83 a
Triticale	45.50 a	40.37 abc	28.37 bc	32.43 bc	36.67 a
oat	31.60 bc	33.57 bc	32.93 bc	39.60 abc	34.43 a
Mean of rates of SAP	34.47 a	37.20 a	34.78 a	36.11 a	

Means followed by the same letter within each factor or interaction are not significantly different at the 0.05 probability level according to Duncan's multiple range test [20].

The results also show significant differences among the values in terms of crops and SAP rates interaction. SAP rates for barley recorded the best records overcome oat and triticale values.

The result in table (10) found that there were significantly differences among the three cereal forage crops regarding the amount of fresh herbage yield per hectare. Oat produced the highest amount of fresh herbage yield comparing with barley which gave the lowest amount. As well as, the table showed there were significant effect of SAP rates on the fresh herbage yield per hectares. The 30 kg/dunam^{-1} recorded the superior values comparing with control and other rates. The study of [7] found similar consequences which indicated that SAP applied for increasing biomass yield in cereal crops. Moreover, [32] revealed that hydrophilic polymer has a positive effect on raise the biomass production in corn. In contrast, excessive rainfall leads to lodging risk by raising plant weight and reducing soil shear strength, while simultaneously altering root activity and nutrient transport as reflected in root-bleeding sap characteristics, same as the finding of [28, 42]. Moreover, [36] support the current study which found that, improvements in tillers number and traits of yield, supported the idea that SAP benefits depend on moisture amount and water stress.

Regarding the interaction between crops and SAP rates, there were significant differences among values. Th whole crops treated with 30 kg/dunam^{-1} of SAP rate showed the highest value comparing with zero treatment and other rates values.

The result in table (11) indicated that there were no significant differences among the crops in terms of dry herbage yield kg per hectare. Moreover, the effect of SAP rates showed no significant differences. There were limit resource show the same findings such as the study of [33] who revealed that there is no significant effect of SAP on

accumulation of biomass in maize. On the other hand, [7] found that biomass increased with SAP treatment in the soil. Also, [24] showed different aspect who reported that SAP leads to enhance the tiller and ear

ISSN 2072-3857

number in the plant and finally increase biomass production. The results of [37] support the idea of the current study which demonstrated that SAP had no significant effect on plant traits and accumulation of biomass when the soil water reach the high level because the plant would utilize a rounded water so that SAP would be absent of activity. [38] also stated that, with high amount of soil moisture, the SAP leads to alter soil physical properties, includingdecreasing bulk density and increasing porosity, water-holding capacity, and swelling and that will cause plant lodging.

In terms of interaction between crops and SAP rates, the result showed that there were significantly differences among the measurements and the highest records was measured for barley at 30 kg/dunam^{-1} SAP rate, while the lowest records were for oat treated by 45 kg/dunam^{-1} of SAP rate.

Table (10) Effect of SAP Rates on Fresh Herbage Yield kg/ha^{-1} of Barley, Triticale and Oat

Crops	Rates of SAP				Mean of Crops
	0 kg/d	15 kg/d	30 kg/d	45 kg/d	
Barley	14783 cde	14547 cde	18383 abc	14357cde	15517 b
Triticale	15423 cde	16183 bcd	19133 ab	13447 cd	16047 ab
oat	15723 cde	16760 abc	20020 a	15450 cde	16988 a
Mean of SAP rates	15310 b	15380 b	19179 a	14418 b	

Means followed by the same letter within each factor or interaction are not significantly different at the 0.05 probability level according to Duncan's multiple range test [20].

Table (11) Effect of SAP Rates on Dry Herbage Yield kg/ha^{-1} of Barley, Triticale and Oat

Crops	SAP rates				Mean of Crops
	0 kg/d	15 kg/d	30 kg/d	45 kg/d	
Barley	3983.3 ab	5016.7 ab	5513.3 a	4200 ab	4678.3 a
Triticale	5270 ab	4573.3 ab	4863.3 ab	5166.7 ab	4968.3 a
oat	4846.7 ab	4253.3 ab	4623.3 ab	3866.7 b	4397.5 a
Mean of SAP rates	4700 a	4614.4 a	5000 a	4411.1 a	

Means followed by the same letter within each factor or interaction are not significantly different at the 0.05 probability level according to Duncan's multiple range test [20].

ISSN 2072-3857

Conclusion:

It can be concluded that, the application of super-absorbent polymer (SAP) at rates of (0, 15, 30, and 45) kg/dunum-¹ had limited effects on the vegetative growth and herbage yield of barley, oat, and triticale forage crops under the environmental conditions of the current study. The most of the evaluated traits were insignificantly affected by SAP application, except for flag leaf area at 15 kg/dunum-¹ and fresh herbage yield at 30 kg/dunum-¹, which recorded significantly higher values than the control and the other application rates. The limited response of the crops may be attributed to the suitable temperatures and relatively high precipitation during the growing season, which likely ensured adequate soil moisture availability and decreased the potential advantage of SAP. Therefore, SAP application might be more effective under drought conditions, particularly in arid and semiarid regions, where its moisture-retention capacity can contribute more substantially to crop growth and forage production. It is recommended that, further studies need to evaluate SAP under different irrigation processes, drought conditions, soil types, and application methods to determine its optimum rate and practical value for forage cereal production.

References:

1- Faostat, (2025). Statistical database. Food and agriculture organization of the United Nations, Rome.

2- Ismael, I. S., & Khalaf, A. S. 2022. Effect of fertilizer types and rates on vegetative traits and fresh herbage yield of winter forage cereals (barley, triticale and oat). Journal of Jilin University (Engineering and Technology Edition), 41(12). https://doi.org/10.17605/OSF.IO/X3QWT

3- Mergoum, M., Sapkota, S., ElDoliefy, A. E. A., Naraghi, S. M., Pirseyedi, S., Alamri, M. S., & AbuHammad, W. 2019. Triticale (x Triticosecale wittmack) breeding. In Advances in Plant Breeding Strategies: Cereals: Volume 5 (pp. 405-451). Cham: Springer International Publishing.

4- Salmon D. F., Cortez M. J., Helm J. H., Jedel P. E., and Duggan T. R. 1997 Registration of 'Pronghorn' triticale Crop Sci. **37** 1392 -1393

5- Baron, V. S., Aasen, A., Oba, M., Dick, C., Salmon, D. F., Basarab, J. A. and Stevenson, F. 2012. Swath-grazing potential for small-grain species with a delayed planting date. Agron. J. 104: 393404.

6- Ribeiro G, Silveira G, Crestani M, Nornberg R, Luche H S, Mezzalira I, Carvalho F I F & Oliveira A C 2011. Diallel analysis in white oat

ISSN 2072-3857

cultivars subjected to water stress. Crop Breeding and Applied Biotechnology 11: 125-132

7- Venkatachalam, D., Kaliappa, S. 2021. Superabsorbent Polymers, A State-of-Art Review on Their Classification, Synthesis, Physicochemical Properties, and Applications. Rev. Chem. Eng. 39, 127–171

8- Miao, J.; Fan, T. 2022. Flexible and Stretchable Transparent Conductive Graphene-Based Electrodes for Emerging Wearable Electronics. Carbon, 202, 495–527.

9- Andry, H.; Yamamoto, T.; Irie, T.; Moritani, S.; Inoue, M.; Fujiyama, H. 2009. Water Retention, Hydraulic Conductivity of Hydrophilic Polymers in Sandy Soil as Affected by Temperature and Water Quality. J. Hydrol., 373, 177–183.

10- Alotaibi, M. M., Alharbi, M. M., Alsudays, I. M., Alsubeie, M. S., Almuziny, M., M. Alabdallah, N., & Awad-Allah, M. M. (2024). Influence of super-absorbent polymer on growth and productivity of green bean under drought conditions. Agronomy, 14(6), 1146.

11- Moslemi, Z., Habibi, D., Asgharzadeh, A., Ardakani, M. R., Mohammadi, A., & Sakari, A. 2011. Effects of super absorbent polymer and plant growth promoting rhizobacteria on yield and yield components of maize under drought stress and normal conditions. African Journal of Agricultural Research, 6(19), 4471-4476.

12- Bashar, A. R. 2016. Response of faba bean (Vicia faba L.) yield, yield components and companion weeds to sowing dates and weed control methods at Duhok governorate (Master's thesis, University of Duhok). University of Duhok, Duhok, Iraq

13- Ismael, I. S. 2023. Effect of fertilizer on growth, yield and its quantity and quality components of some forage crops (Doctoral dissertation, University of Duhok, College of Agricultural Engineering Sciences, Duhok, Iraq).

14- Cereal Seeds, Quality. Performance. Convenience, Cereal seeds guide 2017/18. pggwrigtsongrain.co.nz. https://www.pggwrightsongrain.co.nz/Files/Files/Public/GrainNZ/Product-Dossiers/Cereal-Seed-Guide-201718.pdf

ISSN 2072-3857

15- Meier, U. 2018. Growth stages of mono- and dicotyledonous plants. Julius Kühn-Institut (JKI)

16- GRDC 2015. GROW NOTES. Grain research and development corporation. Canola, section 3, planting. Australia. https://grdc.com.au/resources-and-publications/grownotes/crop-agronomy/canola-south/GrowNote-Canola-South-3-Planting.pdf

17- Shaaban, W. H., & Omer, F. A. 2023. Evaluation of bread wheat cultivars in terms of spike and yield properties under various concentrations of soil and foliar fertilization. Anbar Journal of Agricultural Sciences, 21(2), 261–275. https://doi.org/10.32649/ajas.2023.181833

18- Din, S., Ihsan Ullah, Khan, G. D., Ramzan, M., Ahmad, B., Hameed, M. 2014. Sowing dates and irrigation schedule influenced on yiled and yield components of berseem in district peshawar. Journal of Natural Sciences Research, 4, (9): 2225-0921.

19- Aldesuquy, H., Baka, Z. and Mickky, B. 2014. Kinetin and spermine mediated induction of salt tolerance in wheat plants: Leaf area, photosynthesis and chloroplast ultrastructure of flag leaf at ear emergence. Egyptian Journal of Basic and Applied Sciences, 1: 77-87.

20- Duncan's Multiple Range Test (DMRT) 1955. Multiple range and multiple F tests. Biometrics. 11 (1):1–42.

21- Tas, İ., Coşkun, Y., Tütenocaklı, T., Oral, A., & Akçura, M. 2023. The Effect of Polymeric Hydrogel Application on Germination Under Saline Irrigation Water: Case Study of Barley. Turkish Journal of Agricultural and Natural Sciences, 10(2), 364-370.

22- Islam, M. R., Hu, Y., Fei, C., Qian, X., Eneji, A. E., & Xue, X. 2011. Application of superabsorbent polymer: A new approach for wheat (Triticum aestivum L.) production in drought-affected areas of northern China. Journal of Food Agriculture & Environment, 9, 304-309

23- Moghadam, H. R. T. 2017. Super absorbent polymer mitigates deleterious effects of arsenic in wheat. Rhizosphere, 3, 40-43.

24- Grabiński, J., & Wyzińska, M. 2018. The effect of superabsorbent polymer application on yielding of winter wheat (Triticum aestivum

ISSN 2072-3857

L.). Research for Rural Development, 24(2), 55–61.

25- Jahan, M., & Nassiri Mahallati, M. 2020. Can superabsorbent polymers improve plants production in arid regions?. Advances in Polymer Technology, 2020(1), 7124394.

26- Tao, J., Zhang, W., Liang, L., & Lei, Z. 2018. Effects of eco-friendly carbohydrate-based superabsorbent polymers on seed germination and seedling growth of maize. Royal Society Open Science, 5(2).

27- Abedini, A., & Sajedi, N. A. 2014. Effect of application of a superabsorbent polymer on physiological traits of dry land wheat cultivars. Applied Field Crops Research, 27(103), 140-146.

28- Dingley, C., Cass, P., Adhikari, B., & Daver, F. 2024. Application of superabsorbent natural polymers in agriculture. Polymers from Renewable Resources, 15(2), 210-255.

29- Malik, S., Chaudhary, K., Malik, A., Punia, H., Sewhag, M., Berkesia, N., ... & Boora, K. 2022. Superabsorbent polymers as a soil amendment for increasing agriculture production with reducing water losses under water stress condition. Polymers, 15(1), 161.

30- Sharifan, H., Mirzaie, S., & Seilsepourr, M. 2014. Effect of Different levels of Super Absorbent Polymer and Water Stress on Yield Components of of Forage Corn. Iranian Journal of Irrigation & Drainage, 8(4), 705-712.

31- Bughdady, A., & Shoman, H. E. D. 2021. Effect Of Polymer And Fulvic Acid On Wheat (Triticum Aestivum (L.) Productivity In Sandy Soils Under Environmental Stresses In Egypt. Egyptian Journal Of Desert Research, 71(2), 287-301

32- Dorraji, S.S., Golchin, A. & Ahmadi, S. 2010. The Effects of Hydrophilic Polymer and Soil Salinity on Corn Growth in Sandy and Loamy Soils. CLEAN–Soil Air Water, 38, 584–591.

33- Abdolmaleki, A., Dapprich, P., Bertram, H., Hollensteiner, J., Schmitz, M., Schmitt, A. O., & Gültas, M. 2025. Impact of super absorbent polymers (saps) on the morphological, physiological, and biochemical responses of rapeseed and maize under drought stress. Crop Breeding, Genetics and Genomics, 7(3).

ISSN 2072-3857

34- Zheng, H., Mei, P., Wang, W., Yin, Y., Li, H., Zheng, M., ... & Cui, Z. 2023. Effects of super absorbent polymer on crop yield, water productivity and soil properties: A global meta-analysis. Agricultural Water Management, 282, 108290.

35- Ng'eno, V., Barrera Jr, W., Thine, C., Mbuge, D. O., Obiero, J. P., Dalla Marta, A., & Verdi, L. 2026. A systematic review on the combined effects of deficit irrigation and soil amendment with super-absorbent polymer on crop yield and water productivity. Frontiers in Agronomy, 8, 1785544.

36- Yang, Y., Zhang, S., Wu, J., Gao, C., Lu, D., & Tang, D. W. 2022. Effect of long-term application of super absorbent polymer on soil structure, soil enzyme activity, photosynthetic characteristics, water and nitrogen use of winter wheat. Frontiers in Plant Science, 13, 998494.

37- Abdolmaleki, A., Dapprich, P., Bertram, H., Hollensteiner, J., Schmitz, M., Schmitt, A. O., & Gültas, M. 2025. Impact of super absorbent polymers (saps) on the morphological, physiological, and biochemical responses of rapeseed and maize under drought stress. Crop Breeding, Genetics and Genomics, 7(3).

38- Parvathy, P. C., Jyothi, A. N., John, K. S., & Sreekumar, J. 2014. Cassava starch based superabsorbent polymer as soil conditioner: impact on soil physico-chemical and biological properties and plant growth. Clean–Soil, Air, Water, 42(11), 1610-1617.

39- American Chemical Society. (2025, December 22). Sodium polyacrylate. Molecule of the Week. https://www.acs.org/molecule-of-the-week/archive/s/sodium-polyacrylate.html

40- ISTA, Rules, 2013. International Seed Testing Association. International Rules for Seed Testing, edition. ISTA Basserdorf, CH. International Seed Testing Association web site. www.seedtest.org

41- Rajak, P., Afreen, T., Raghubanshi, A. S., & Singh, H. 2025. The impact of rainfall variability on selected soil properties and Eco physiological traits in Prosopis juliflora invaded plots. Scientific Reports, 15(1), 31473.

42- Niu, L., Feng, S., Ding, W., & Li, G. (2016). Influence of speed and

ISSN 2072-3857

rainfall on large-scale wheat lodging from 2007 to 2014 in China. PloS One, 11(7), e0157677.

ISSN 2072-3857