EFFECT OF NITROGEN FERTILIZER AND SUPERABSORBENT POLYMERS (SAPS) ON BIOLOGICAL TRAITS, NITROGEN AND WATER USE EFFICIENCY OF SUMMER SQUASH (*CUCURBITA PEPO* L.)

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Abstract

To evaluate the effect of various nitrogen and superabsorbent polymers (SAPs) levels on nitrogen use efficiency, absorption and productivity, and water use efficiency of summer squash (*Cucurbita pepo* L.), two experiments were conducted in two cropping years 2018-2019 and 2019-2020 in western, Iran . The experiments were conducted as a split plot arrangement with three replications based on a randomized complete blocks design. The experimental treatments consisted of superabsorbent polymers (SAPs) s at four levels (control, 40 kg ha^{-1}, 80 kg ha$^{-1,}$ and 120 kg ha^{-1}) as the main plot factor and pure nitrogen fertilizer as urea (46% N) at four levels (control, 50 kg ha^{-1}, 100 kg ha^{-1} and 150 kg ha^{-1}) as sub plotfactor. The results revealed that the yield and yield components of Summer squash increased with the application of superabsorbent polymers (SAPs) and nitrogen fertilizer. When 120 kg ha^{-1} of superabsorbent polymers (SAPs) and 150 kg ha^{-1} of nitrogen were applied, the highest increase was observed in fruit weight, seed weight, percentage of seed nitrogen, leaf dry weight, and stem dry weight. Although there were no significant differences between treatments of 40 and 80 kg ha^{-1} superabsorber and 100 and 150 kg ha^{-1} nitrogen, fruit weight increased with co-application of 80 kg ha^{-1} superabsorbent polymers (SAPs) and 150 kg ha^{-1} nitrogen. Thus, the application of 40 kg ha^{-1} superabsorber and 100 kg ha^{-1} nitrogen can be both economically and environmentally beneficial. Furthermore, using 120 kg ha^{-1} of superabsorbent polymers (SAPs) and 150 kg ha^{-1} of nitrogen improved seed water use efficiency, fruit water use efficiency, and nitrogen productivity and nitrogen absorption Additionally, the highest nitrogen use efficiency was obtained when 120 kg ha^{-1} of superabsorbent polymers (SAPs) was applied. However, the use of nitrogen by 50, 100, and 150 kg ha^{-1} had no significant effect on this trait; hence, it can be concluded that the use of nitrogen by 50 kg ha^{-1} is recommended from an economic and environmental point of view.

Keywords: Nitrogen, superabsorbent polymers (SAPs), Summer squash , Nitrogen use efficiency, Water use efficiency.

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Introduction

Medicinal plants are considered natural gifts by human society and have been used since ancient times as effective means of pain relief. Summer squash (*Cucurbita pepo* L.) is one of the most valuable medicinal plants in the pharmaceutical industry of most developed countries. Nitrogen is an essential element for plants, increasing dry matter production, grain yield, and component attributes (Nazari – Nasi et al., 2018). The method of absorption, the nitrogen use efficiency, and can be influenced by factors such as soil available water content, soil fertility, and plants competition (Baigonussova, et al., 2021). Approximately 40 to 60 percent of the nitrogen fertilizer added to the soil is removed from the soil via agricultural products, and this amount decreases with further fertilization. The result is a higher amount of fertilizer remaining in the soil, which reduces nitrogen use efficiency, leaches easily, and contaminates water sources (Safavi-Gardini et al., 2016). In recent years, the highly hydrophilic superabsorbent polymers (SAPs) polymers (SAPs) have been used as an additive to the soil and a potential reservoir for some nutrients and water in agriculture (Leyte-Marique,et al., 2021). These materials have shown an effective role in decreasing the effects of drought stress, and also in increasing the productivity for both crops and horticultural plants (Nekoho et al., 2016). Increasing irrigation intervals as a result of application of superabsorbent polymers (SAPs) hydrogels has been considered as a basic strategy in order to save and use water efficiently (Jahan and Amiri., 2019).The properties of these materials depend on many factors, including their composition and chemical properties, method and quantity of application, soil texture, plant species, and also environmental conditions (Jahan and Amiri., 2019).Globally, drought is one of the most significant factors limiting agricultural production, and this issue is even more acute in arid and semi-arid regions. About one-third of the Earth's surface is covered by arid and semi-arid regions, which span 45 million km^2. More than 1.5 million km^2 of Iran's soils are classified as arid or semi-arid regions (FAO, 2018), where water is the main limiting factor for agriculture. Even though more than 90% of the water extracted in the country is consumed by agriculture, the irrigation efficiency with current methods is estimated at 32% (Karimi et al., 2017). Water use efficiency plays a major role in plant adaptation to dry conditions and is influenced by water, soil, and crop management (Fatima, et al., 2021). Two indices of irrigation efficiency and water use efficiency in Iran are almost 32% and 0.7 kg m^{-3}, respectively, which must reach 1.3 kg m^{-3} to obtain self-sufficiency (Nikbakht and Rezaee., 2017). Considering the importance of the cultivation of medicinal plants and the effects of nitrogen fertilizer and water superabsorbent polymers (SAPs) hydrogels on plant growth and development, also the objective of this study was to investigate the effect of different nitrogen fertilizers and superabsorbent polymers (SAPs) on nitrogen use efficiency, nitrogen absorption, and productivity, and water use efficiency of summer squash during two consequtive cropping years (Nikbakht and Rezaee., 2017).

Materials and Methods

The experiment was carried out in the city of Kermanshah in the west of Iran,. The longitude was 47^{O} , 6$^{/}$ and the latitude was 34^{O} , 18$^{/.}$ According to the coupon method, the climate of this region is semi-arid and cold. The average annual temperature is 14.3^{OC} The experiment was conducted as a split-plot design based on randomized complete blocks with three replications. The experimental treatments consisted of moisture superabsorbent polymers (SAPs) s at four levels (control, 40 kg ha^{-1}, 80 kg ha$^{-1,}$ and 120 kg ha^{-1}) as the main factor and pure nitrogen fertilization obtained from urea at four levels (control, 50 kg ha^{-1}, 100 kg ha^{-1} and 150 kg ha^{-1}) as sub-factor. In early June, after preparing the field with plowing and disking and applying superabsorbent polymers (SAPs) , manual sowing was conducted. The planting rows were 5 m long, the distance between the seeds on the rows was 40 cm and the rows were 4 m apart. A distance of 1 m. was considered as corridor between plots and blocks. To achieve adequate density, plants were thinned at the 4-leaf stage. Weed control was performed manually. The soil texture was silty-loam. The soil samples were taken at a depth of 0-30 cm before planting and were analyzed (Table 1). The following formulas were used to calculate the efficiency of water, nitrogen and nitrogen efficiency.

$$\frac{\text{Yield}}{\text{Total Water Used}} = \text{Water Use Efficiency(WUE)}$$

Ntrogen Use Efficiency (NUE) = Yield/ N supply

N supply: Soil nitrate at the time of cultivation is mineralized nitrogen in the soil and consumed nitrogen.

NUtE(kg/ kg) = Yield/ N uptake

N uptake : Total nitrogen uptake by biomass

SAS statistical software (version 6.12) was used for variance analysis. Duncan's test was used to compare the means.

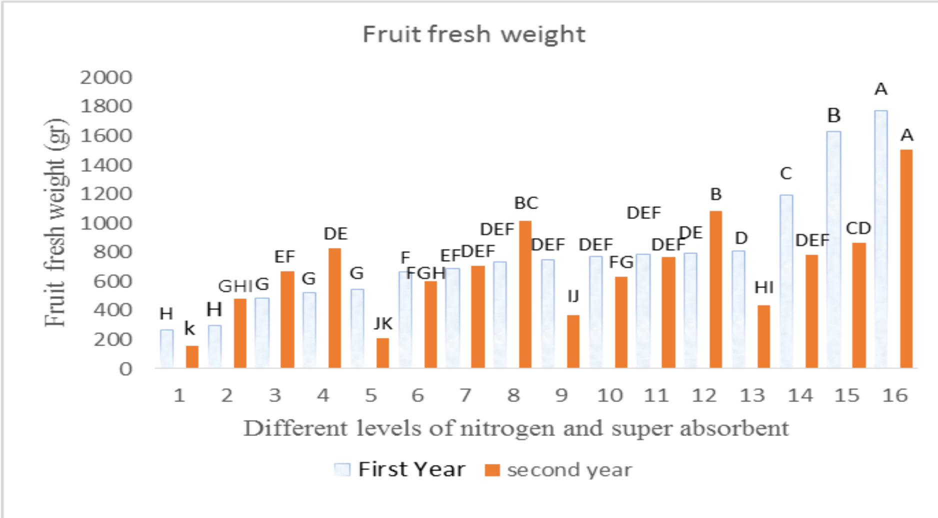
Phosphorous (%)	Potassium)ppm(	pH	Nitrogen (%)	Organic carbon (%)	Sand (%)	Silt (%)	Clay (%)	Texture	Depth)cm(
20.06	282	7.5	0.17	1.5	16.7	39	44.3	Silty-loam	0-30

Table 1. Physiochemical characteristics of the study site soil

Results and Discussion

Fruit fresh weight

Results revealed that superabsorbent polymers (SAPs) , nitrogen and their interaction affected the fresh weight of fruits significantly over a period of two years (Table 2,3). The co-application of 120 kg ha^{-1} superabsorbent polymers (SAPs) and 150 kg ha^{-1} N resulted in the highest average fresh weight while the lowest one was related to control treatment, So that this treatment indicated an approximately 57% increase compared to the control. According to results, at different levels of superabsorbent polymers (SAPs) , this trait increased with enhancing consumed nitrogen. The primary reason for this rise could be the availability of moisture provided by increasing the consumption of superabsorbent polymers (SAPs) and improving the amount of available N to the plant, leading to increased vegetative growth; and ultimately, higher fresh fruit weight. Additionally, there was no significant interaction of 40 and 80 kg ha^{-1} superabsorbent polymers (SAPs) and 100 and 150 kg ha^{-1} of N treatments in terms of this trait. The higher fresh weight and greater consumption of both N and moisture superabsorbent polymers (SAPs) may indicate the availability of moisture and nitrogen since N is the main nutrient necessary for vegetative growth, which results in higher fresh weight (Fig 1). Similarly,(Hamzei and Hosseini., 2022) reported that by increasing the consumed N in summer squash, the fruit fresh weight was increased.



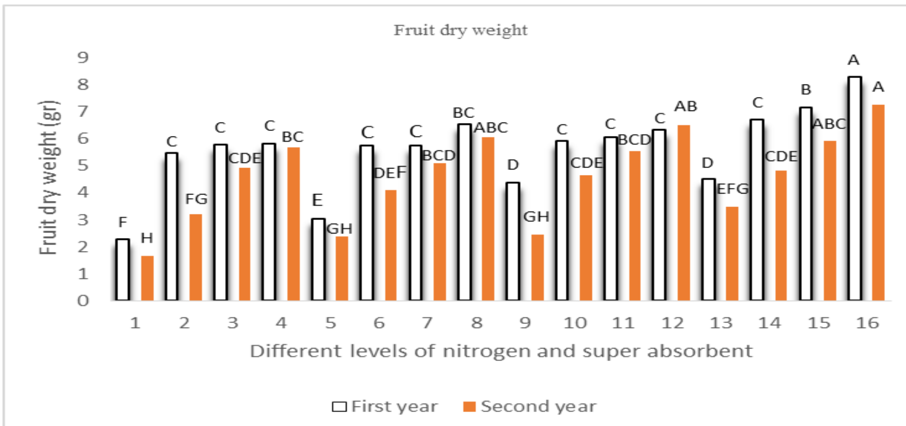
Means followed by the same letters in each column are not significantly different (p≤ 5%)

Fig 1. Effect of nitrogen fertilizer and superabsorbent polymers on Fruit fresh weight

1: Nitrogen 0 + Super Adsorbent 0	9: Nitrogen 80 + Super Adsorbent 0
2: Nitrogen 0 + Super Adsorbent 50	10: Nitrogen 80 + Super Adsorbent 50
3: Nitrogen 0 + Super Adsorbent 100	11: Nitrogen 80 + Super Adsorbent 100
4: Nitrogen 0 + Super Adsorbent 150	12: Nitrogen 80 + Super Adsorbent 150
5: Nitrogen 40 + Super Adsorbent 0	13: Nitrogen 120 + Super Adsorbent 0
6: Nitrogen 40 + Super Adsorbent 50	14: Nitrogen 120 + Super Adsorbent 50
7: Nitrogen 40 + Super Adsorbent 100	15: Nitrogen 120 + Super Adsorbent 100
8: Nitrogen 40 + Super Adsorbent 150	16: Nitrogen 120 + Super Adsorbent 150

Fruit dry weight

According to results, superabsorbent polymers (SAPs) , nitrogen and their interaction significantly affected fruit dry weight (Table 2, 3). There was a maximum average of this trait in the interaction of 120 kg ha^{-1} superabsorbent polymers (SAPs) and 150 kg ha^{-1} nitrogen treatment , whereas the lowest one was achieved in the control treatment, so that this treatment increased fruit dry weight about 73% compared to the control. Results revealed that with different levels of superabsorbent polymers (SAPs) along with increased nitrogen, the dry weight of the fruit was enhanced. Moreover, there was no significant difference between the interaction of control, 40, and 80 kg ha^{-1} of superabsorbent polymers (SAPs) and 50, 100, and 150 kg ha^{-1} of nitrogen treatments (Fig 2). (Moradi et al., 2016) found that increasing nitrogen consumption in summer squash led to increased fresh weight and biomass of the fruits.



Means followed by the same letters in each column are not significantly different (Duncan multiple range test 5%)

Fig 2. Effect of nitrogen fertilizer and superabsorbent polymers on Fruit dry weigh.

Fruit number per plant

The main effects of superabsorbent polymers (SAPs) and nitrogen on fruit number per plant were not significant in the first year of the experiment, while their main and interaction effects were significant in the second year. The highest average of this trait across two-year experiment was recorded for the treatment of 150 kg ha^{-1} N2 and 120 kg ha^{-1} superabsorbent polymers (SAPs) , while 50, 100 and 150 kg ha^{-1} nitrogen treatments were not significantly different.The lowest fruit number was recorded for the control treatment. In addition, it is notable that the difference between 100 and 150 kg ha^{-1} of N application at different levels of superabsorbent polymers (SAPs) was not significant during two years of experiment. Considering that the number of fruits per plant was not influenced by nitrogen and superabsorbent polymers (SAPs) application, it can be claimed that this trait is largely influenced by its specific genetic characteristics and does not respond greatly to environmental conditions (Fig 3).(Hamzei and Hosseini.,2022) also reported similar results in their studies.

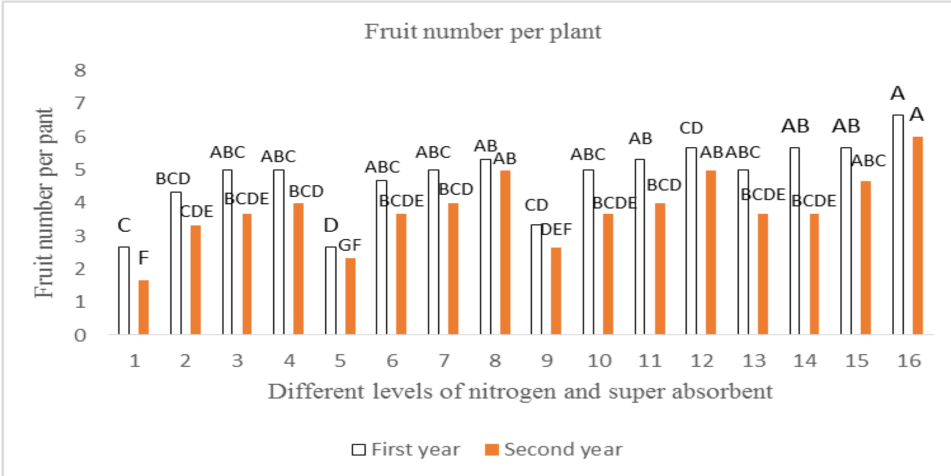


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Fig 3. Effect of nitrogen fertilizer and superabsorbent polymers on Fruit number per plant.

Grain weight

Results indicated that there was a significant effect of superabsorbent polymers (SAPs) , N, and interaction of these two factors on grain weight during two years of experiment (Table 2,3). Mean comparison results showed that the highest grain weight was obtained from application of 150 kg ha^{-1} of N, and 120 kg ha^{-1} of superabsorbent polymers (SAPs) , while the lowest one, was achieved from the control treatment. This could be explained by increasing seed storage simultaneously with higher application rated of nitrogen and superabsorbent polymers (SAPs) (Fig 4). (Nekoho et al., 2016) also stated similar results on pumpkin.

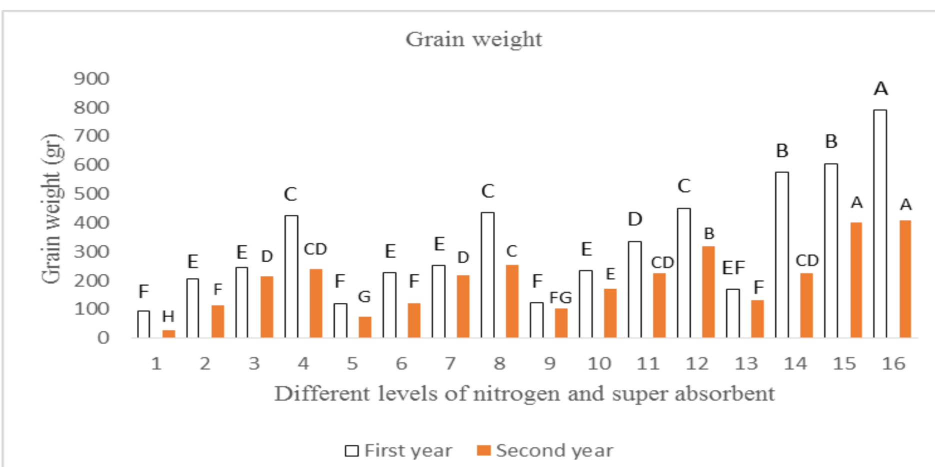

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Fig 4. Effect of nitrogen fertilizer and superabsorbent polymers on Grain weight

Grain number per fruit

Application of superabsorbent polymers (SAPs) , N and their interaction significantly affected grain number per fruit across both years of experiments (Table 2,3). Mean comparison results of this trait showed that during both years, the highest number of grains per fruit was associated with N application at 150 kg ha^{-1}, and 120 kg ha^{-1} of superabsorbent polymers (SAPs) (Fig5).

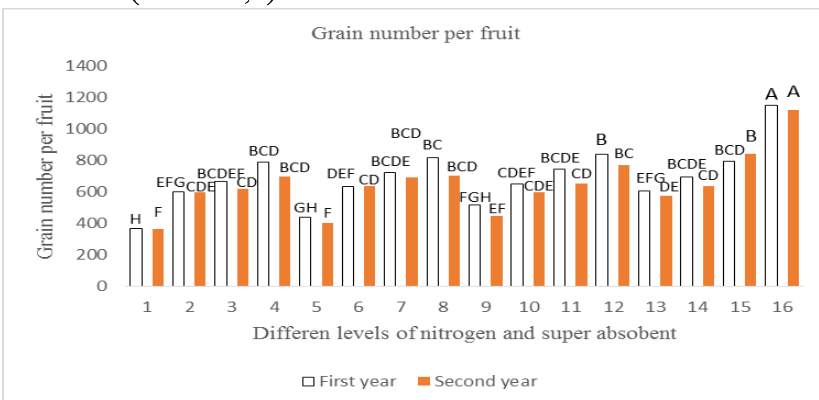

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Fig 5. Effect of nitrogen fertilizer and superabsorbent polymers on Grain number per fruit.

Water use efficiency (WUEseed)

As shown in Table 2,3 and Fig 6 superabsorbent polymers (SAPs) and nitrogen and their interaction had a significant effect on the seed water use efficiency during the two years of study. The highest WUE was recorded with the co-application of 120 kg ha^{-1} superabsorbent polymers (SAPs) and 150 kg ha^{-1} nitrogenIncreasing the use of superabsorbent polymers (SAPs) s by providing moisture to the plant with adequate nitrogen enhances the water use efficiency. According,(Cheikh et al., 2018) increased nitrogen application to Summer squash plants increases WUE. Since nitrogen fertilizer levels do not differ in terms of seed WUE, 50 kg of nitrogen fertilizer per hectare appears to be a desirable application from an environmental and economic point of view. Reducing the use of absorbents may result in less available water and the potential for moisture stress, leading to a greater decrease in photosynthesis compared with plant respiration. This can be attributed to damaged leaf mesophyll as a consequence of drought stress. Also, the increase in mesophyll and stomatal resistance due to drought stress conditions can reduce the entry of carbon dioxide into plant tissue, decreasing net photosynthesis, water use efficiency, and productivity (Rizvani Moghadam et al., 2022 ; Nekoho et al., 2016).

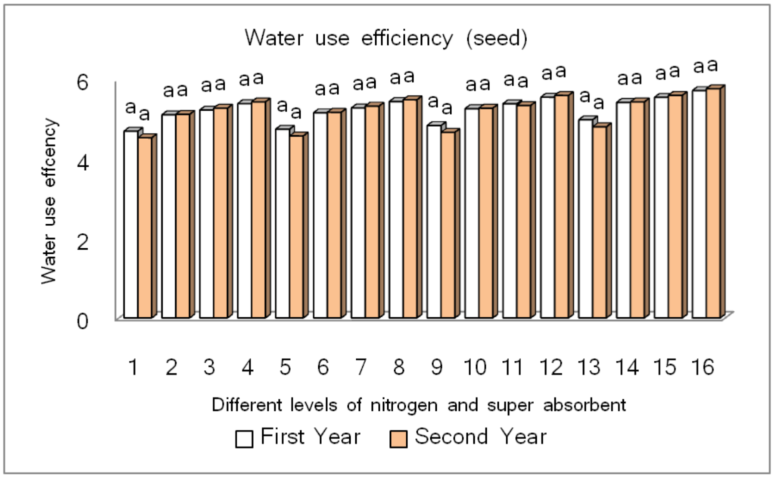

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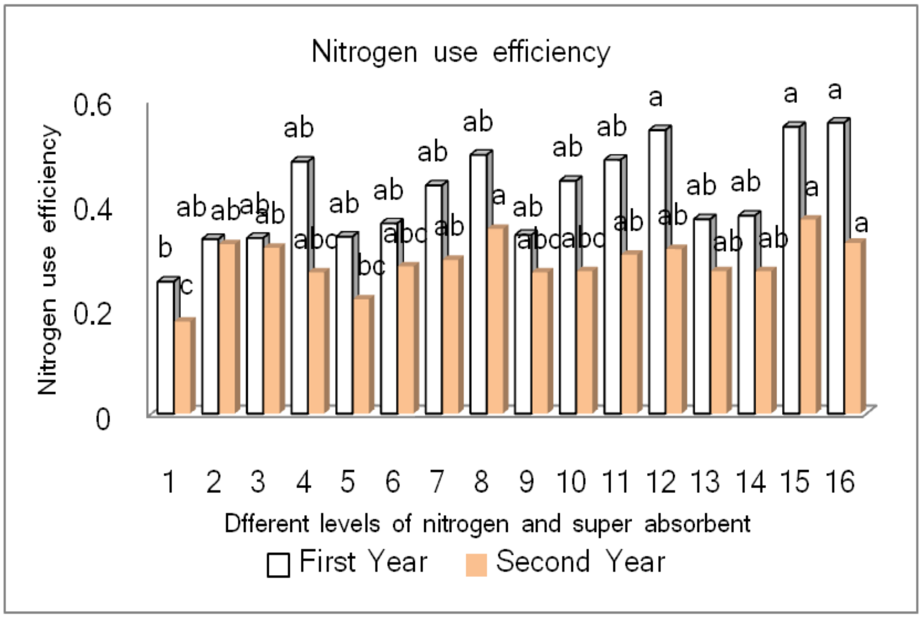
Fig 6. Effect of nitrogen fertilizer and superabsorbent polymers Water use efficiency

Nitrogen use efficiency (NUE)

In the first year, superabsorbent polymers (SAPs) , nitrogen, and the interaction of superabsorbent polymers (SAPs) and nitrogen significantly increased nitrogen use efficiency (Tables 2, 3). At all superabsorbent polymers (SAPs) levels, NUE increased with N fertilizer use. Nitrogen application at 150 kg ha^{-1} contributed to this characteristic mostly. Generally, no significant difference was found between nitrogen levels. There are studies indicating that it is difficult for plants to absorb nutrients, especially nitrogen when moisture is scarce and their wastage increases, making nitrogen use less efficient (Karimi, 2018).It is recommended to use less nitrogen to reduce pollution and economic costs because there is no significant difference in nitrogen consumption between the current rates of nitrogen application. The decrease in NUE associated with high nitrogen fertilizer use is caused either by an increase in nitrogen losses through leaching and sublimation or by a lack of effective nitrogen use (Majdam et al., 2017). A study on wheat was conducted by Khan et al. (2017) found that the efficiency of nitrogen fertilizer decreased with increasing quantity. According to the law of diminishing return, nitrogen use efficiency decreases simultaneously with nitrogen application (Ahmadi, 2016).It has also been suggested that nitrogen use efficiency decreases under such conditions due to sublimation, denitrification, no uptake of nitrogen due to its lower solubility, or no effective utilization of this element in large quantities (Ahmadi, 2016; Khan et al., 2017).

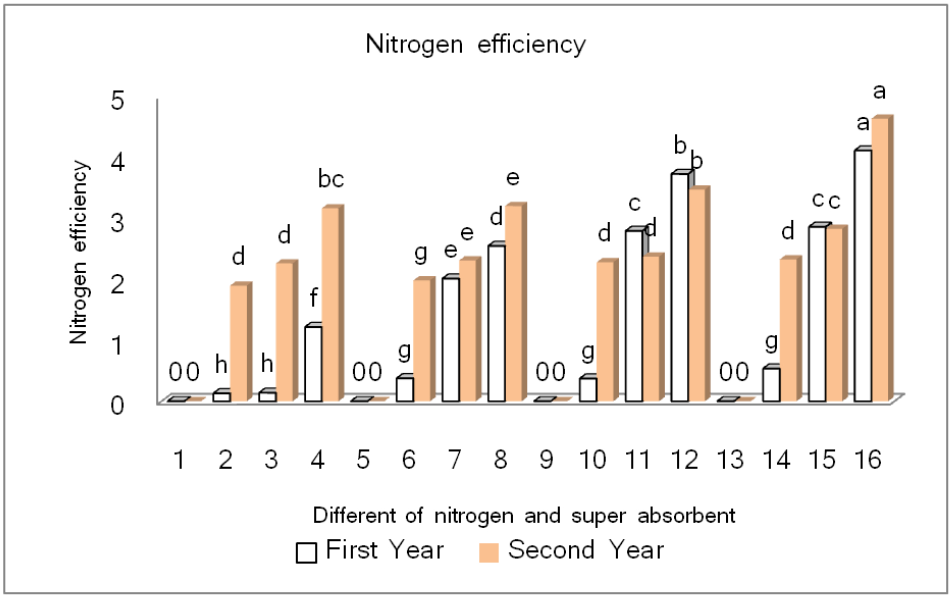


Means followed by the same letters in each column are not significantly different (Duncan multiple range test 5%)

Fig 7. Effect of nitrogen fertilizer and superabsorbent polymers on Nitrogen use efficiency

Nitrogen productivity

Nitrogen productivity was significantly affected by superabsorbent polymers (SAPs) , nitrogen, and superabsorbent polymers (SAPs) and nitrogen interaction (Tables 2, 3). In the two years of experimentation, the highest value of this trait was found in the 150 kg ha^{-1} and 120 kg ha^{-1} superabsorbent polymers (SAPs) treatments, which was significantly different from the other levels. Since the nitrogen productivity does not follow the law of diminishing returns and is highly dependent on grain yield, this index value did not increase linearly. Moreover, there was no significant difference between various levels of applied nitrogen for this index. In a study by (Hamzi and Hosseini., 2022) nitrogen fertilizer use decreased nitrogen productivity.



Means followed by the same letters in each column are not significantly different (Duncan multiple range test 5%)

Fig 8. Effect of nitrogen fertilizer and superabsorbent polymers on Nitrogen efficiency

2. Table of Analysis of variance (1 Years)

SOV.	Fruit fresh weight	Fruit dry weight	Fruit number per plant	Grain weight	Grain number per fruit	Nitrogen use efficiency	Nitrogen productivity	Water use efficiency (grain)
Repetition	1.44	43719.56	0/06	599.91	1907.6	5.66	0.05	0.001
Superabsorbent polymers (SAPs)	3.119*	197776.2**	2.243^{ns}	516592.477**	43906.743**	4736.23**	20.67**	0.001*
Error1	0.56	44015	0.7	551.91	8072.87	5.10	0.94	0.0001
Nitrogen	5.288*	323448.746**	1.632^{ns}	48246.026**	86032.576**	459.52**	0.59**	0.001^{ns}
N*S	8.249*	106970.921**	4.706^{ns}	2110.92	122577.428**	117.24**	1.08**	0.001^{ns}
Error2	1.40	3868.96	1.04	2110.92	8262.84	19.42	0.01	0.001
CV.	21.11	7.84	21.21	13.91	13.18	11.32	10.43	10.54

* and ** mean significant at 5% and 1% probability, respectively. ns means non-significant.

SOV.	Fruit fresh weight	Fruit dry weight	Fruit number per plant	Grain weight	Grain number per fruit	Nitrogen use efficiency	Nitrogen productivity	Water use efficiency (grain)
Repetition	0.35	28835.3	0.02	1276.67	6953.52	11.93	0.01	0.001
Superabsorbent polymers (SAPs)	0.95^{ns}	324820.43**	3.18*	45170.91**	69348.02*	416.62**	4.56**	0.001*
Error1	0.45	14327.42	0.43	457.61	8000.85	4.27	0.1	0.0001
Nitrogen	6.91**	1278620.30**	2.18*	12445.05**	54218.18**	1164.59**	1.81**	0.001^{ns}
N*S	10.2	40276.38**	4.26**	3095.05**	116197.29**	29.44**	0.49**	0.001^{ns}

	7**							
Error2	0.61	9880.29	0.55	365.68	8377.52	3.39	0.06	0.001
CV.	18.08	6.37	20.24	14.34	12.18	10.36	11.56	9.47

3. Table of Analysis of variance (2Year)

* and ** mean significant at 5% and 1% probability, respectively. ns means non-significant.

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