



Original Article

Saffron Flower and Stigma Yield Changes in Response to Application of Different Levels of super Absorbent Polymer

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Abstract

Saffron production will be increased in arid regions by providing sufficient water through appropriate agronomic strategies. Therefore, in this investigation the impact of different rates of super absorbent polymer (SAP) including 0, 10, 20, 30, 40 and 50 kg ha⁻¹ was studied on saffron flowering traits during two growth cycles. Results showed that the influence of experimental factor was significant on almost all studied indices in both years. Number of flower was on average 22% more than control when 30-40 kg ha⁻¹ SAP was used. Flower yield in the first growth cycle was higher in 40 kg ha⁻¹ (24.9 g.m⁻²) and in the second one in 30 kg ha⁻¹ (89.4 g.m⁻²) SAP application, while these values in control treatment were 19.7 and 71.2 g.m⁻² for the first and second seasons, respectively. Altogether in two years application of 40 kg ha⁻¹ SAP produced the highest fresh stigma + style yield (4.54 g.m⁻²) compared with the control (3.47 g.m⁻²). SAP application at the rates of more than 30 kg ha⁻¹ increased dry stigma yield in average of two years (0.45, 0.50, 0.49 and 0.44 g.m⁻² for 0, 30, 40 and 50 kg.ha⁻¹ treatments, respectively). In addition, SAP usage at the rate of 40 kg ha⁻¹ produced the highest number (12.6) and weight (86 g per plant) of replacement corms at the end of second growth season. In total, it seems that SAP consumption can be considered as a suitable option for improvement of saffron flowering in areas affected by drought stress.

Keywords: *Crocus sativus*, Drought stress, Sepal yield, Style yield, Water availability

Introduction

Almost one-third of the world lands are located in arid and semi-arid areas which are faced to drought stress [1]. Reduction in water resources availability in these regions has created real concerns about agricultural production and food security. At the same time with the increase in world population, the arable lands per capita and access to water resources are decreasing. Accordingly, limited water resources including rainfall and irrigation

water should be used more efficiently with higher productivity [2]. Given the world's growing need for food, the use of lands under environmental stresses is taken into attention. In these areas, application of strategies such as the use of more resistant crops to abiotic stresses is very important [3]. Saffron (*Crocus sativus* L.), as a summer dormant and winter active medicinal-spicy herb is an appropriate candidate for these areas, because it is one of the most efficient plants in terms of water consumption [4,5].

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Saffron stigma with more than 150 components has many household and industrial applications like as a colorant and flavoring agent in cooking as well as use in medical and perfumery industries [6]. This small and cormous crop is cultivated in 87000 ha of arable lands with 300-ton annual dry stigma production in Iran which includes about 90% of its world production [4,7]. Saffron growth cycle is coinciding with the rainy season from mid-fall to mid-spring, which makes it very appropriate for arid and semi-arid regions [6]. Despite of low water requirement of saffron this plant responses positively to appropriate water availability in terms of corm growth and flower production. However, because of limited access to water resources in the distribution area of saffron, the plant will be faced with drought stress during its growing cycle [8]. Therefore, development of approaches such as super absorbent polymer (SAP) application is a main step for crop production in arid and semi-arid regions [9].

SAPs are hydrophilic compounds with a great potential for water and nutrients maintenance for plant growth [2]. Previously the positive impacts of water absorbent materials such as zeolites [10] and SAP [8,11] has been evaluated on sprouting rate and corm growth traits of saffron. However, there is no sufficient information about the flowering response of saffron to SAP application at the field conditions. Therefore, this study aimed to investigate the impact of six levels of SAP on saffron flower and stigma yield during two growing seasons.

Material and Methods

For evaluation the impact of superabsorbent polymer (SAP) rates on flowering parameters and underground traits of saffron an experiment was conducted at Research Field of Sarayan Faculty of Agriculture, University of Birjand, Iran during two growing seasons (2013-14 and 2014-15). Sarayan as one of the main saffron producing areas in Iran is located in 33°N, 58°E and has 1450 masl. Its climate is characterized with annual long-term rainfall and temperature of 120 mm and 17 °C, respectively. The amount of rainfall during first and second saffron growth cycle (November to June) was 80 and 115 mm, respectively. In addition, mean temperatures during saffron growth were 13.5 and 14.7 °C for two studied years.

Experimental treatments were six SAP rates (0, 10, 20, 30, 40 and 50 kg.ha⁻¹) that were arranged in a randomized complete block layout with three replications. The used SAP was made of potassium polyacrylate and polyacrylamide copolymers (Table 1). Given the important role of water and soil quality in water holding capacity of SAP, some physio-chemical characteristics of irrigation water and soil used in the experiment are shown in Table 1.

Soil preparation was done in the beginning of autumn. At this time 30 t ha⁻¹ cow manure, 100 kg.ha⁻¹ potassium sulfate and 50 kg.ha⁻¹ urea were used as pre planting. Saffron mother corms (mean weight of 5.95g) were planted in 14th October, 2013. In each plot (2.5 m² area), 900 g corm was planted in rows with 20 cm distances and planting depth of 20 cm. Plant distance on the row was 8 cm and corm planting was as single corm, in which one corm was planted in each planting point. SAP was used manually below and beside of mother corms. First irrigation was performed immediately after corm planting and then irrigation was applied five times during two growth seasons with almost monthly intervals (Nov. 6, Dec. 6, Jan. 6, Feb 6. and April 6). Moreover, one-time summer irrigation was applied in 6th August, 2014. Hand weeding also was applied one time during plant growth season at mid-February in both growing seasons.

Saffron flower picking was made daily during autumnal flowering phase of two years (2014 and 2015). In each harvesting date the flowers were counted and weighed separately in each plot. Then, the petals were separated from stigma and style. Drying of main saffron flower parts was made at ambient temperature (25 °C) and shade condition for 14 days. Finally, dry stigma, style and petals weights were determined with accuracy of 0.001 g. For evaluation of the effects of experimental treatments on the underground traits of saffron five plants were lifted from the soil at the end of second growth cycle (10th May, 2016) and then number and weight of replacement corms were determined. Data analysis was made using SAS 9.1 and means were compared by Duncan's multiple range test at 5% level of probability.

Results and Discussion

Flower Number and Yield

SAP application affected significantly the flower number and yield of saffron (Table 2). In the first growth cycle the highest flower number was obtained at the rate of 40 kg ha⁻¹ SAP consumption and there were no significant differences between other levels. In the second growth season application of more than 30 kg ha⁻¹ SAP, produced more flowers compared with lower levels of SAP. Mean number of flower in all levels of SAP during both years (105 flower.m⁻²) was 14% more than control with 91 flowers per square meter (Fig 1). Similar result was obtained for flower yield, where application of higher levels of SAP (30-40 kg ha⁻¹) had partially a positive effect on this trait, but treatments of 10 and 20 kg ha⁻¹ SAP consumption had no-significant difference with control. The highest flower yield was obtained at the rate of 30 kg ha⁻¹ SAP application in the second growth cycle that was 20% more than control (Fig. 2).

Flowering capacity in saffron is highly dependent on corm weight and the number of flowering buds per corm [12]. Our previous findings also revealed that SAP consumption has an increasing impact on corm growth indices of saffron, where the amounts of mean weight of replacement corms and mean number of buds per corm increased by 29 and 27% with application of 40 kg ha⁻¹ SAP compared with control treatment, respectively [8]. This increase in corm growth criteria is mainly related to

appropriate water availability in saffron rhizosphere by SAP application [11], because SAPs are hydrophilic networks that can absorb and retain huge amounts of water or aqueous solution [13]. Overall, application of more than 30 kg.ha⁻¹ SAP was a suitable way for saffron flower production. The lower effect of 50 kg.ha⁻¹ SAP on flowering of saffron is because of rodent damage in this treatment which leads to unexpected results (Personal observations). Saffron flowering in the second growth season was more than the first one (Fig 1 and 2). These is due to the increase in number and weight of replacement corms during years, when saffron is cultivated as a perennial crop.

Stigma and Style Yields

Effect of SAP application was significant on fresh and dry weights of saffron style and stigma (Table 2). In both growing season consumption of 40 kg.ha⁻¹ SAP produced the highest yield of fresh stigma + style that was 24% more than control. On average of five SAP treatments during both studied years the amount of pistil (stigma + style) yield was only 5% higher than control (Fig 3). Dry stigma yield was increased partially with application of 30-40 kg.ha⁻¹ SAP. Mean stigma yield during two studied growth cycles was 9 and 7% more than control in 30 and 40 kg.ha⁻¹ SAP consumption, respectively. So that, stigma dry yield in 0, 30 and 40 kg.ha⁻¹ treatments was 4.51, 5.05 and 4.88 kg.ha⁻¹, respectively.

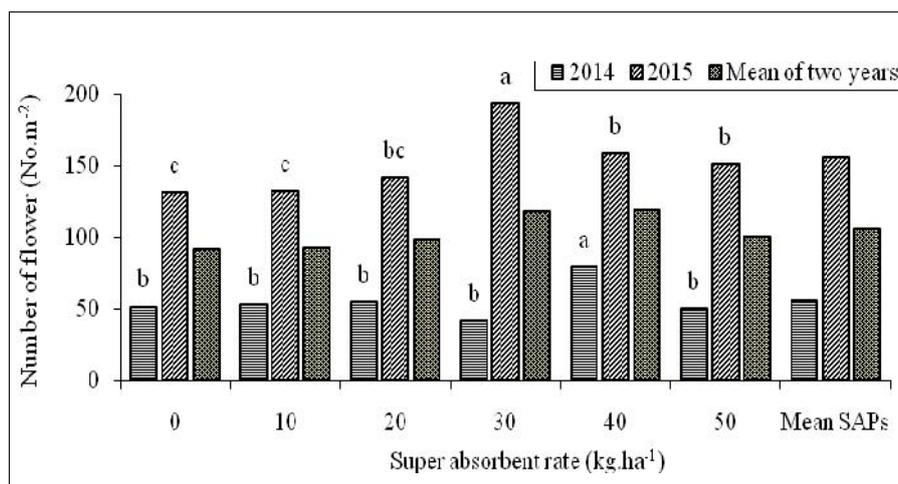
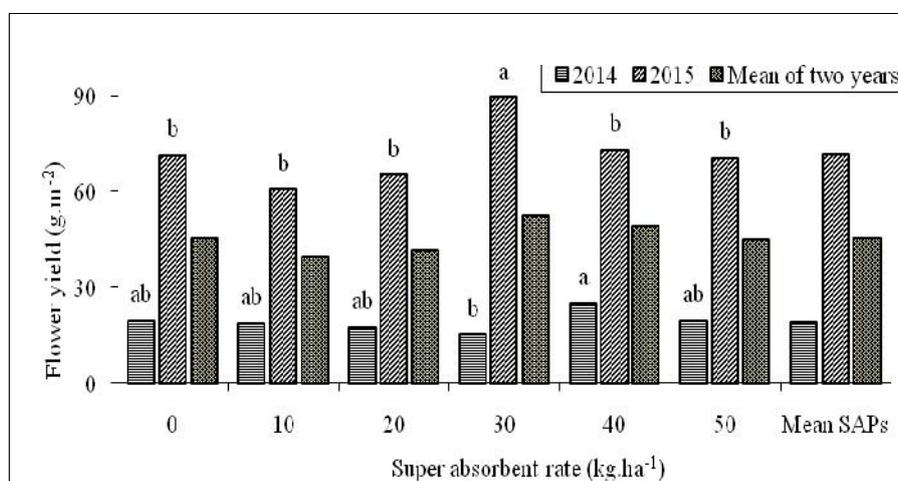
Table 1 The main characteristics of soil, irrigation water and superabsorbent polymer used in the research.

Superabsorbent properties							
Appearance	Density (g.cm ⁻³)	Grain size (mm)	pH	EC (μm cm ⁻¹)	Moisture (%)	Maximum durability (year)	Water holding capacity (g.g ⁻¹)
White granule	1.1-1.5	0.5-1	7.4	1754	11.6	7	330
Irrigation water properties							
EC (μm)	pH	TDS (ppm)	Ca ²⁺ (ppm as CaCO ₃)	Mg ²⁺ (ppm as CaCO ₃)	Na ⁺ (ppm)	K ⁺ (ppm)	Cl ⁻ (ppm)
1300	7.81	8510	48	51.5	156.4	0.45	170.4
Soil properties (0-40 cm)							
Sand (%)	Clay (%)	Silt (%)	Soil texture	pH	EC(ms/cm)	SP	SAR
53.5	19.4	27.1	Loam	7.62	8.85	28.3	13.2
OC (%)	N _{total} (%)	P _{ava} (ppm)	K _{ava} (ppm)	CaCO ₃ (%)	Gyp (%)	Ca (meq/lit)	TDS
0.25	0.021	6.27	249	14.9	1.55	14.9	5660

Table 2 Analysis of variance (sum of square) for the effect of different levels of super absorbent polymer on the saffron flowering indices

Source of variation	df	Number of flower		Fresh yield of flower		Fresh yield of pistil		Dry stigma yield		Dry style yield		Dry petals yield	
		2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
Replication	2	133 ^{ns}	1648 ^{**}	36 ^{ns}	827 ^{**}	0.11 ^{ns}	3.1 [*]	0.002 ^{ns}	0.08 ^{**}	0.0000 ^{ns}	0.0048 ^{**}	0.30 [*]	1.5 ^{ns}
Treatment	5	2355 ^{**}	7964 ^{**}	156 ^{ns}	1429 ^{**}	1.32 [*]	14.4 ^{**}	0.022 ^{**}	0.12 ^{**}	0.0011 [*]	0.0180 ^{**}	6.64 ^{**}	28.2 ^{**}
Error	10	777	854	145	426	0.77	2.1	0.006	0.034	0.0005	0.0029	0.39	6.5
Total	17	3266	10466	338	2683	2.21	19.77	0.031	0.23	0.0016	0.258	7.35	36.3

^{ns}, ^{**} and ^{*}: no-significant and significant at 1 and 5% levels of probability based on Duncan multiple range test

**Fig. 1** Effect of SAP application on the number of saffron flower per square meter**Fig. 2** Effect of SAP application on saffron flower yield per square meter

However, application of less than 30 kg.ha⁻¹ SAP had no increasing effect on stigma yield (Fig 4). Similar result was obtained for dry style yield, where only SAP application at the rates of 30, 40 and 50 kg.ha⁻¹ improved it by 28, 22 and 13%, respectively (Fig. 5). Therefore, positive effects of SAP levels were partially more effective on increasing style yield compared with stigma weight (Fig 4 & 5). Overall, we concluded that SAP application at the rate of 30-40 kg ha⁻¹, may

increase the dry stigma yield by 0.5 kg ha⁻¹ annually. This yield improvement is equal to about 30,000,000 Rials that is considerably higher than SAP costs (8,000,000 Rial during its durability which is 7 years, equal to about 1,140,000 Rial per year).

In similar pot experiment, Khorramdel *et al.*, [11] concluded that dry weight of stigma increased by increasing SAP rate from 0 to 0.8%. They recommended SAP application in saffron field

which are located at arid and semi-arid areas especially with unsuitable soil texture. Usage of SAP_s under water deficit conditions will lead to improved soil moisture conditions, provided a longer growing period and increased sink capacity [14] as corm weight as the main sink of photo-assimilates in saffron has been increased by SAP application in previous studies [8,11]. The beneficial effects of SAP on growth of plants are related to improvement of plant viability and emergence, preventing from nutrients leaching, reduction in water stress, improvement in soil ventilation, increase in soil porosity, increase the rainfall use efficiency and enhance soil microbial communities' activity [8,15]. It must be taken into account that SAP profitability is highly dependent on water quality, so that in a study by increase in salt concentration from 0 to 0.2 and 1.2%, its water absorbent capacity decreased from 300 to 120 and 50 g.g⁻¹, respectively [2]. In current study the

amount of monovalent (Na⁺, K⁺, Cl⁻) and divalent (Ca²⁺, Mg²⁺) ions in irrigation water was about 0.042% (Table 1). Therefore, the actual ability of SAP for distilled water absorption was not obtained at real saffron farm condition.

Petal Yield

Petal dry weight of saffron showed a significant response to different levels of SAP application (Table 2). By considering of two years, application of 30 kg.ha⁻¹ SAP produced the highest amount of petal yield that was 11% more than control (Fig. 6). Sepal is the by-product of saffron flowers which can be considered as a natural source of anthocyanin's to be used in food industries [6]. In previous studies the positive effects of SAP application on growth and yield of many plants such as canola [16], safflower [14] and cumin [9] have been reported, especially under water stress conditions.

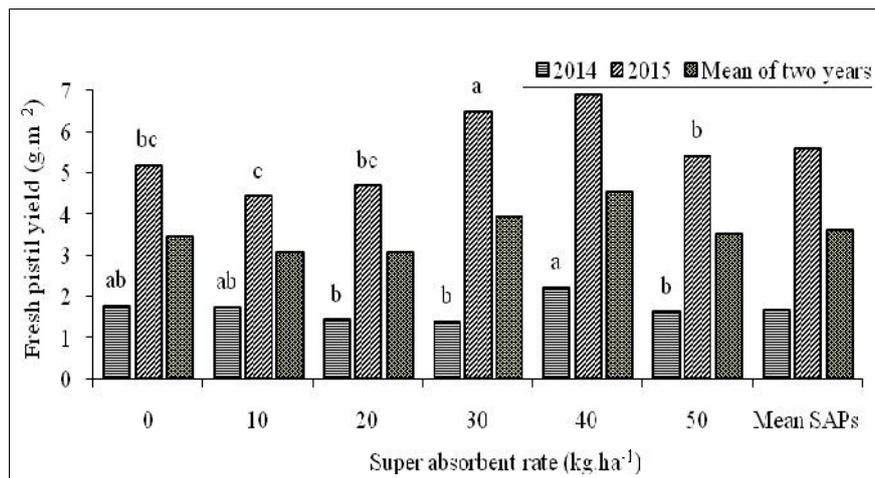


Fig. 3 Effect of SAP application on saffron fresh style + stigma yield per square meter

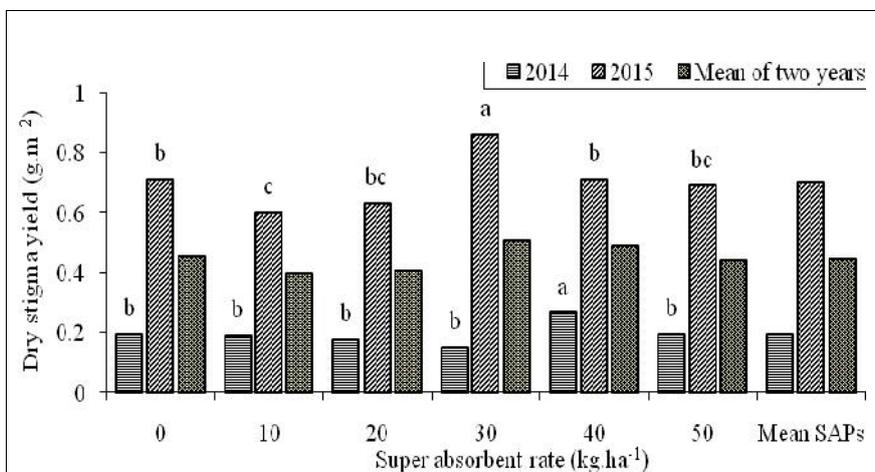


Fig. 4 Effect of SAP application on saffron dry stigma yield per square meter

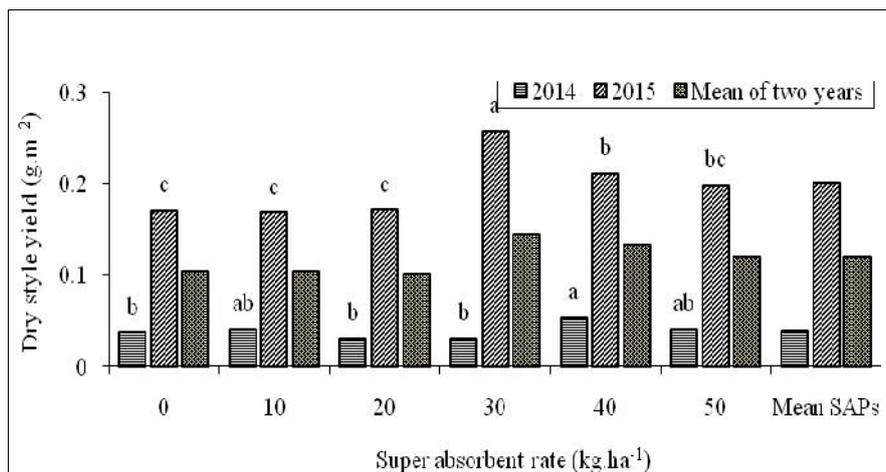


Fig. 5 Effect of SAP application on saffron dry style yield per square meter

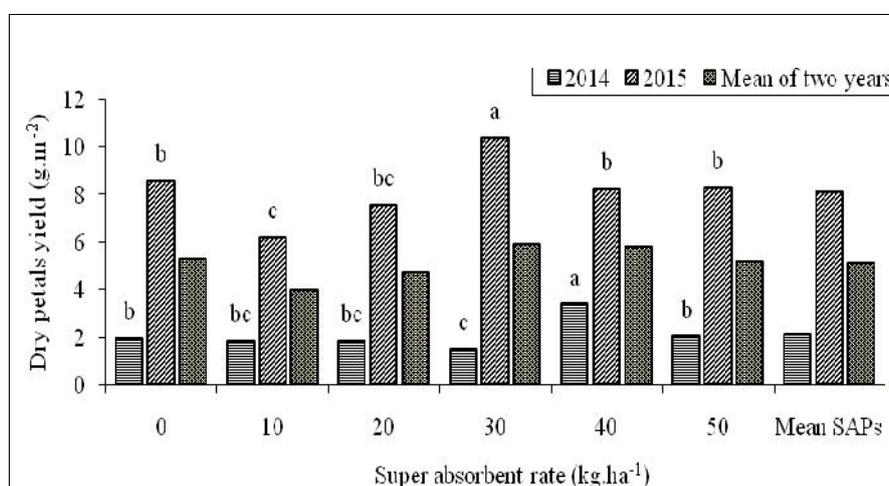


Fig. 6 Effect of SAP application on saffron dry petals yield per square meter

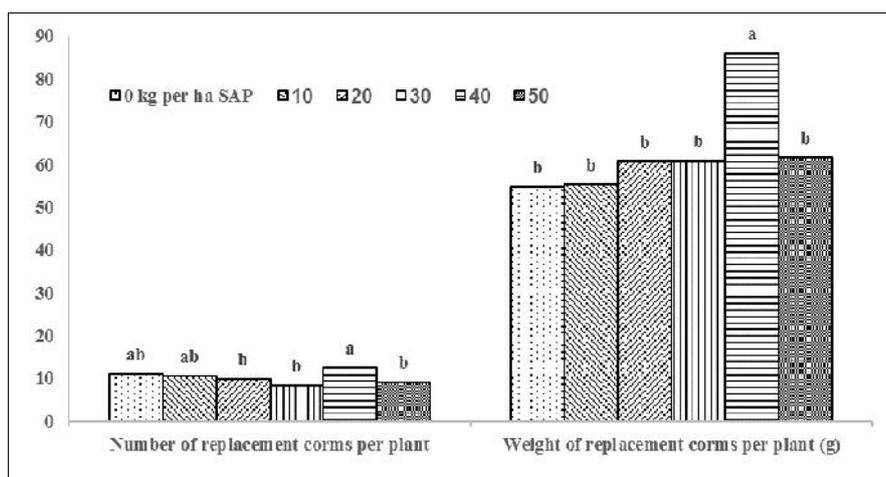


Fig. 6 Effect of SAP application on number and weight of replacement corms of saffron at the end of second growth season

It has been reported that SAP could reserve considerable amounts of irrigation and rainfall water. Therefore, increase in soil water content will be resulted to better plant growth and yield under water deficiency [16].

Underground Traits

Application of 40 kg ha⁻¹ SAP increased the number of replacement corms per plant, while there was no-significant different between other levels of

SAP and control treatment. Different rates of SAP had an increasing effect on the total replacement corms weight per clone. The highest amount of this index obtained in treatment of 40 kg ha⁻¹ SAP, which was 37% more than control treatment (Fig. 7). Accordingly, mean replacement corm weight was obtained 4.97, 5.26, 6.19, 7.33, 6.82 and 6.69 g for 0, 10, 20, 30, 40 and 50 kg ha⁻¹ SAP application, respectively. SAP application accelerates cell division in corm by providing more moisture. Moreover, these materials can enhance leaf growth and consequently more photo-assimilates partitioning to corms. These processes increase the growth indices of saffron replacement corms [8,11].

Conclusion

Stigma dry yield as the main yield component in saffron was not affected by below 20 kg.ha⁻¹ SAP application. However, consumption of 30-40 kg.ha⁻¹ SAP increased stigma yield by 9% compared with the control treatment, so that, these rates of SAP produced 4.96 kg.ha⁻¹ stigma in mean of two years, while this amount for control was 4.51 kg.ha⁻¹. This increase in stigma yield has considerable economic income for Iranian farmers that the mean production of their fields is 4 kg.ha⁻¹. Nevertheless, we could offer a clear recommendation when more experiments with higher levels of SAP, other soils and water qualities in other areas and new SAP structures be conducted.

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