

Effect of Potassium Fertilization Source on Strawberry Yield and Quality

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Abstract: The purpose of this research is to investigate the effect of potassium fertilizer source by fertigation on strawberry productivity and quality parameters. The trial was conducted during 2015-2016 in the experimental greenhouse of the Hassan II Agronomic and Veterinary Sciences of Rabat. Strawberry plants of the cultivar 'Fortuna' were planted on October 13th in 40 liter pots equipped with a gravity fertigation system. Tested treatments were (1) Potassium sulfate for the whole growing cycle (PS/PS) (2) Potassium Nitrate during the vegetative period and Potassium sulfate during the fruit production period (PN/PS) and (3) potassium Nitrate for the whole growing cycle (PN/PN). An experimental block design with three repetitions was adopted. The total amounts of applied nitrogen, phosphorus, potassium, magnesium and calcium are identical for all potassium source treatments. Potassium sulfate has a slightly higher electrical conductivity than potassium nitrate source, 1.9 dS/m and 1.6 dS/m respectively. While the two solutions have a similar pH of 6.1. The average yield obtained is 900 g with a slight advantage for the PN/PS treatment. These differences potassium fertilization source are not statistically significant. The measured parameters of fruit quality in the normal range for strawberries with an average Brix degree of 5.3, a juice acidity level of 0.35 to 0.65 % and a dry matter content of 7.8 at 9.0 %. These strawberry quality parameters were not significantly affected by potassium fertilization source. We concluded that the both sources, potassium sulfate and potassium nitrate, have equivalent effects on strawberry productivity and quality.

Keywords: Strawberry, Fertilization, Potassium, Source, Potassium Sulfate, Potassium Nitrate, Productivity, Quality

1. Introduction

In recent years, Morocco has known a considerable development in red fruit sector (strawberries, raspberries and blueberries), achieving an estimated turnover of 3.76 billion Dh with a planted area extending over 11,400 ha [1].

During the 2020-2021 crop year, the overall raspberry area amounted to 4100 Ha and generated a production of approximately 45,700 T, mainly intended for export. Regarding blueberry cultivation, it occupied an area of 3900 Ha and generated a production of nearly 47,000 T [1].

Although the development of blueberries and raspberries is faster, strawberry cultivation still occupies a prominent place in the red fruit sector with 29% of the total area cultivated with red fruits in Morocco (3400 ha) and represents over than 50% of Moroccan red fruit exports [1]. Indeed, the strawberries

production has reached, during the same agricultural campaign, 102,000 T of which 80% are intended for export in fresh or frozen state. Due to these statistics, Morocco has become the 10th largest strawberry exporter in the world.

To be more competitive on the export strawberry market, it is necessary to ensure not only the quantity of fruit, but also their quality. Indeed, a strawberry marketing is essentially conditioned by quality parameters [2], of which sugar content (Brix), acidity content and visual appearance are the main determinants [3].

It is recognized that an excess or deficiency of fertilizers can have important consequences on yield, quality and profitability of vegetable crops. Strawberry fertilization is particularly challenging since this crop is one of the most

sensitive horticultural plants due to its superficial root system, pH requirement and sensitivity to nutrient solution salinity and chlorine [4, 5].

The fertilizers choice, their application timing and the appropriate doses remain the key factors ensuring good yield and quality fruits.

Potassium is an essential mineral element for strawberry, which require large amounts [6] and it plays significant roles in the production and transfer of proteins and sugars, the regulation of water movements in the plant and the improvement of plant tolerance to diseases and pests [7]. Potassium is considered a determining factor in the quality of strawberries, since sugar and vitamin C levels as well as fruit acidity tend to increase with the potassium fertilization dose. In addition, potassium plays an essential role in the transfer of assimilates to the fruits. A reduction in the transport of assimilates limits the productivity and quality of strawberries and is often a consequence of a potassium deficiency [8].

For a yield of 60 tonnes/ha of strawberries, potassium requirements in the Loukkos region amount to approximately 300 kg K₂O/ha [9]. In this region, strawberry fertilization is conducted by fertigation throughout the cycle, as it is a technique that maximizes productivity by reducing environmental impact [10] and increases fertilizer use efficiency [11]. The available sources of potassium to strawberry growers and usable in fertigation are Potassium chloride (PC), Potassium Nitrate (PN) and Potassium Sulfate (PS). The choice of the adequate potassium source used in strawberry fertigation depends on several factors including in particular its solubility, salinity index, action on the soil pH, the effect of the anion accompanying potassium (Cl⁻, SO₄²⁻ or NO₃⁻) and its price per unit of supplied potassium. The Potassium chloride source is not recommended for strawberries because of their high sensitivity to salinity due to chlorine. The other two sources of potassium fertilizers (PS and PN) are the most widely used by strawberry growers in Loukkos [12]. Strawberry growers favor the PN source during the first part of the cycle when the average temperature is low and the PS source from flowering.

This research work aims to study the effect of the potassium fertilization source on the productivity and quality of strawberries through a pot test in an experimental greenhouse.

2. Material and Methods

2.1. Experimental Site and Substrate

Agronomic trial was conducted in the experimental greenhouse of the Hassan II Institute of Agronomy and Veterinary Sciences in Rabat during the 2015-2016 agricultural campaign. The substrate used is a mixture of an equal volume of sandy soil, collected from coastal areas, and commercial peat. The growing substrate has a grain size dominated at 78% by fine sand, such as strawberry cultivation areas in Morocco (Table 1). Substrate pH is slightly acidic and moderately rich in organic matter and mineral macro-elements (Table 1).

Table 1. Physico-chemical characteristics of the trial culture substrate.

Parameter	Sandy soil	Prepared substrate
Granulometry		
Clays %	5,5	6,6
Fine silts %	2,4	1,7
Coarse silt %	6,2	0,5
Fine sands %	72,1	78,2
Coarse sands %	13,8	13
Chemical characteristics		
pH	7,8	6,2
Electrical conductivity mmhos/cm	1,1	1,8
Total limestone %	0	1,6
Organic matter %	0,4	4,6
Ammonium mg/kg	10,9	13,7
Nirate mg/kg	9,0	151,8
Assimilable phosphorus mg/kg	43,6	72,8
Assimilable potassium mg/kg	36,0	172

2.2. Plant Material and Potassium Source Treatments

Five plug plants of the 'Fortuna' variety were planted in 40-liter pots, equipped with a drip fertigation system. Originally from Florida, it is one of the three strawberry cultivars widely adopted in the Loukkos region [13].

The experimental potassium fertilization treatments tested combine the potassium fertilizer source (PN or PS) and the period of its application:

- (1) PS/PS: Potassium sulfate during the whole cycle;
- (2) PN/PN: Potassium nitrate during the whole cycle;
- (3) PN/PS: Potassium nitrate during the vegetative period and potassium sulfate during the fruit production period (Practice of strawberry farmers in Loukkos).

An experimental block design was adopted with three experimental treatments replicated thrice making a total of nine experimental objects. Each treatment consisted of a pot containing five strawberry plants fertilized once a week. The total nitrogen, phosphorus, potassium, magnesium and calcium application dose was identical for the all potassium fertilizer source treatments (160 kg/ha N, 165 kg/ha P₂O₅, 300 kg/ha K₂O, 55 kg/ha CaO and 14 kg/ha MgO).

2.3. Fertigation Management

The pots were equipped with fertigation tanks, drip irrigation systems and drains with taps to collect the drainage and allow fertigation management.

Fertigation solutions were applied daily by adjusting the irrigation dose based on the drained water volume which is maintained between 10 and 20% of the supplied water volume [14] and by measuring the pH and electrical conductivity of the nutrient solutions and drainate which should meet the specific requirements of strawberry¹.

2.4. Agronomic Measurements

In order to evaluate the effects of potassium fertilizer source and the timing of its application in fertigation on production and quality of strawberry fruit, parameters related to the

¹ EC=1 à 2 dS/m et pH=5,5 à 6,5 [15-16].

growth, production and quality of hand harvested strawberries were measured every week.

The parameters recorded were:

1. Flowering dynamics consisted of counting the number of flowers per plant;
2. Fruit yield measured through the cumulative weight of strawberry production during the whole harvest period which lasted 14 weeks;
3. Sugar content in fruit (°Brix) measured by placing 1 to 2 drops of clear juice fruit on the prism of a digital refractometer (HI 96801, HANNA). The prism of the refractometer was washed with distilled water and dried between samples;
4. Titratable acidity of fruit juice determined by titration method using a benchtop pH meter (CONSORT P107), the titrated volume of 0.1 M NaOH was recorded to an endpoint of pH 8.1 [17];
5. Dry matter content of strawberries of which the sampled fresh fruits were weighed and then oven dried at 80 deg C temperature for 48 hours before being weighed their dry weight [17].

2.5. Statistical Analysis

The obtained data were statistically analyzed using SYSTAT 13 statistical software. The analysis of variance (ANOVA) was performed for each parameter studied to assess significant differences at the 5% level in treatments for all parameters.

Comparison of the treatment means was performed using the Newman-Keuls test at significance level of 5% probability.

3. Results and Discussion

3.1. Electrical Conductivity and PH of Fertigation Solutions

Electrical conductivity (EC) and pH were regularly measured for irrigation water, fertigation solutions, as well as

the drained water. The PN fertigation program of the stock solution has a high EC of 6.1 dS/m and an acidic pH of 4.8 (Table 2). PS solution has a slightly higher EC and a more acidic pH than PN.

In this trial, the electrical conductivity of the fertigation solution was around 1.7 dS/m for the both treatments PS and PN (Table 1). The nutrient solution pH for these treatments was on the order of 6. These values are in the range of strawberry plants requirements which are 1 to 2 dS/m for electrical conductivity and 5.5 to 6.5 for pH [15, 16].

In fertigation, the electrical conductivity of the nutrient solutions impacts the productivity and quality of the strawberry fruits. Indeed, electrical conductivity values above our values reduce strawberry yield due to its high sensitivity to salinity [18] and a properly managed electrical conductivity of the fertigation solutions allow to obtain a better fruit quality [19].

Table 2. Electrical conductivity and pH of irrigation water, fertigation solutions and drained water for each potassium fertilizer source treatment.

Treatment	Electrical conductivity (dS/m)	pH
Irrigation water	0,50	8,07
Stock solution	PN	6,10
	PS	8,70
fertigation solution	PN	1,56
	PS	1,87
Drained water	PN	2,19
	PS	2,14

PN: Potassium Nitrate, PS: Potassium Sulfate.

3.2. Flowering Dynamics

In our study, the number of flowers had evolved in several periods of flowering during the strawberry cycle with a maximum of 16 flowers per pot (Figure 1). The two salient peaks in flower production were observed in mid-November and mid-March. During the cycle, each strawberry plant produced a total of about 25 flowers.

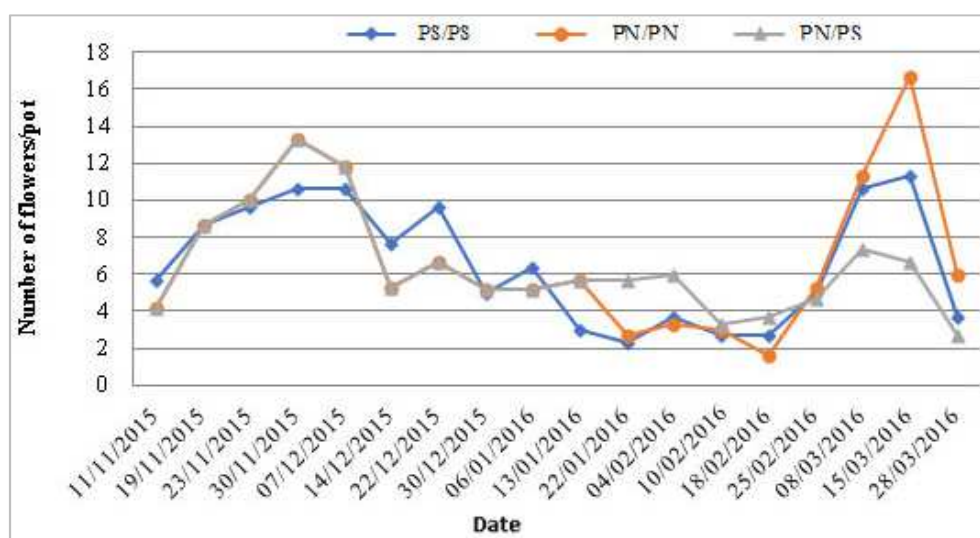


Figure 1. Evolution of the number of flowers produced during the strawberry cycle for all potassium fertilizer source treatments.

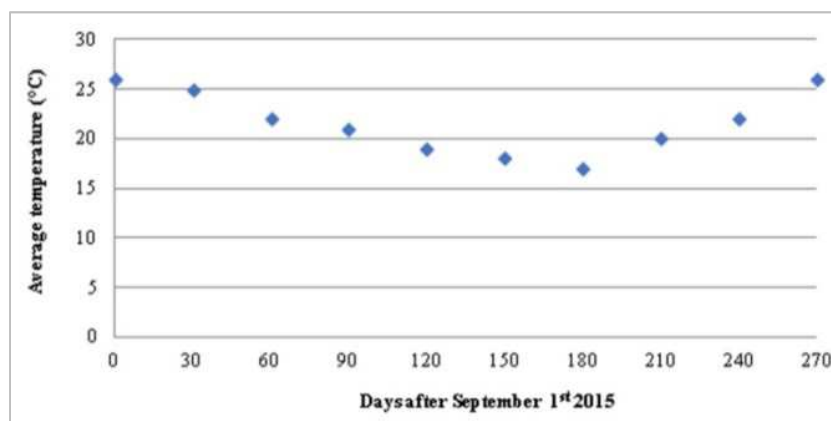


Figure 2. Average daily outdoor temperature from September 1st, 2015 at the trail site in Rabat.

No significant difference was found between the potassium fertilizer source treatments. The flowering dynamics of our strawberry plants seem to be more influenced by the effect of temperature than the source of potassium fertilization [20-22]. This dependence of flowering on temperature is supported by the parallelism between daily mean temperature (Figure 2)

and flower production (Figure 1). The total number of flowers produced during the first and second period of strawberry cycle as well as total number of flowers produced during the whole cycle, are in the same order for all potassium fertilizer source treatments (Figure 3).

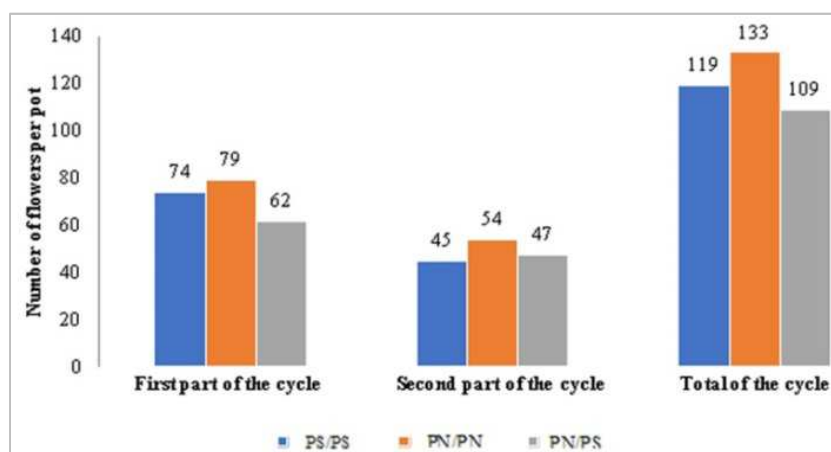


Figure 3. Number of flowers produced per pot and per period of the strawberry cycle for all potassium fertilizer source treatments.

3.3. Strawberries Yield

Strawberry harvesting began two months after planting and was carried out once a week throughout the 14-week production period. The average yield obtained for all treatments is 900 g/pot (Figure 4). The potassium fertilization source did not significantly affect total fruit yield (Figure 5). It should be noted that at this level, the source of potassium fertilization is the only difference between the experimental treatments. The fertilization doses of nitrogen, phosphate, potassium, magnesium and calcium were strictly identical between all potassium source treatments.

The application of PN during the vegetative period followed by PS during the fruit production period had a slightly better effect on yield, compared to the application of the PN or PS source alone throughout the cycle. Our results corroborated those reported by Hochmuth and Hanlon [23] and Lester *et al.* [24], who confirmed that there is a little

significant effect of the potassium fertilization source on crop yield, in contrast to the potassium fertilizer dose, which generally and significantly increases yield. Indeed, strawberry production was improved with potassium fertilization regardless of the source [25].

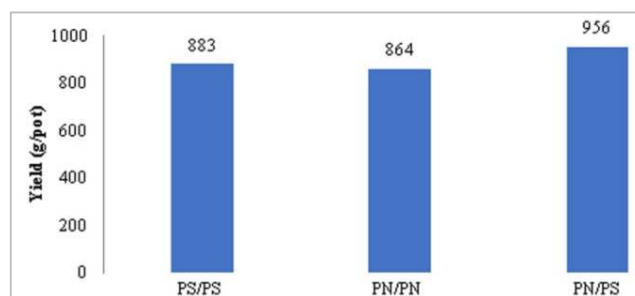


Figure 4. Cumulative strawberries yield for all potassium fertilizer source treatments.

Several studies have shown that there is little or no effect of

potassium fertilization source on strawberry yield [26, 27] and on other fruit and vegetable crops such as tomato [28, 29], potato [30, 31], and citrus [32, 33].

3.4. Strawberries Sugar Content

The average Brix degree recorded in our trial is 5.3 with a variation interval of 3.5 to 7 (Figure 5). The sugar content of strawberries generally ranges from 4.6 to 11.9% [34, 35].

Throughout the production period, the average Brix degree ($^{\circ}$ Brix) of the PS/PS, PN/PN and PN/PS treatments is 5.7, 5.8 and 5.3, respectively. The PS or PN source of potassium fertilization had a slightly higher $^{\circ}$ Brix level than their alternating combination (PN/PS) (Figure 5). However, these differences in Brix degree between the potassium fertilization source treatments are not statistically significant.

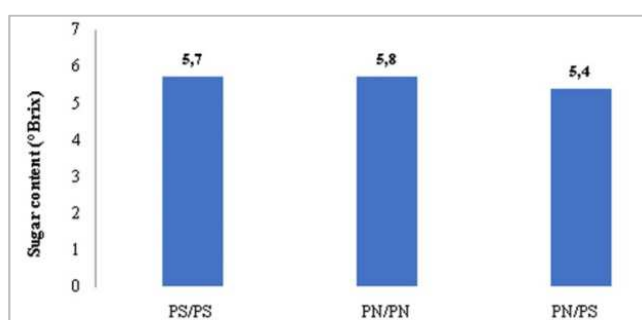


Figure 5. Sugar content of strawberry fruits under all potassium fertilizer source treatments.

Potassium is an essential mineral element that significantly influences many fruit and vegetable quality compounds [36-38] determining their market value and thus consumer preferences [24-39]. Indeed, Davies and Winsor [40] and Dorais *et al.* [41] had observed the positive impact of potassium on tomatoes acidity, sugar content and organoleptic quality of. In strawberries, the results obtained by Ebrahimi *et al.* [42], Maldonado *et al.* [43] and Rodas *et al.* [44], showed that potassium fertilization improved sugar content. However, Locascio *et al.* [28] reported that the potassium fertilizer source had a little effect on fruit sugar content.

In an experimental trial comparing potassium fertilizers sources, it was observed that potassium sulfate (PS) improved sugar content of strawberry fruits more than potassium chloride (PC) [27].

3.5. Strawberries Acidity Content

The titratable acidity of strawberry fruits juice measured throughout the production period for all potassium fertilization sources ranged from 0.35 to 0.65 % (Figure 6). These values are within strawberry acidity standards ranging from 0.5 to 1.8 % [34-45].

In our trial, the potassium fertilizer form did not significantly affect the acidity content of strawberry fruit. According to Ahmad *et al.* [46], potassium fertilization could increase the fruits acidity in parallel with the sugar content.

In the same context, some studies had been carried out to compare different forms of potassium fertilizers on fruit

acidity, they showed that potassium fertilization improved the acidity content of banana fruits [47], kiwifruit [48] and guava [49]. He [48] also observed that potassium sulfate (PS) improved the acidity content of fruits more than potassium chloride (PC).

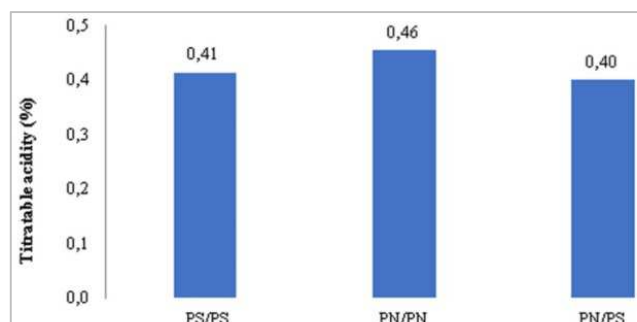


Figure 6. Strawberry acidity content under all potassium fertilizer source treatments.

3.6. Strawberries Dry Matter Content

The average dry matter content of strawberries harvested in our trial during the crop cycle varied from 7.8 to 9.0% (Figure 7). Strawberry fruit dry matter content usually varies within a range of 7 to 11% depending on the variety [50] or the fertilization programs [51].

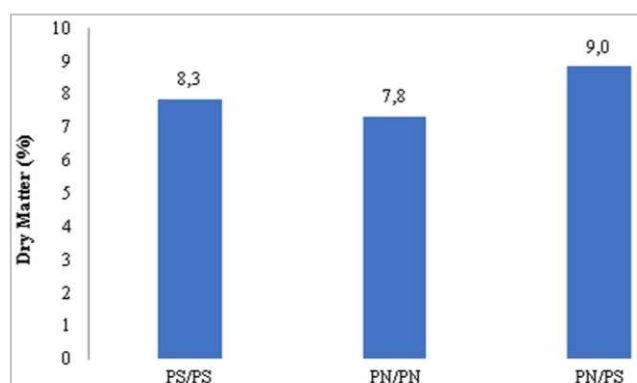


Figure 7. Dry matter content of strawberry fruits for all potassium fertilizer source treatments.

Potassium fertilization improved the dry matter of many crops such as apple [52], guava [53], lychee [54], papaya [55], pepper [56], as well as other vegetables [57]. In our study, the potassium fertilization source treatments including potassium sulfate (PS/PS and PN/PS) generated a dry matter rate slightly higher than that with potassium nitrate alone (PN/PN) (Figure 7). Similar results were obtained from experiments comparing potassium fertilizer sources applied to the soil, they showed that the application of potassium sulfate (PS) improved dry matter of pepper more than potassium nitrate [56] and of vegetables more than potassium chloride [57].

4. Conclusion

The potassium fertilizer source to be used in fertigation depends on several factors, including its solubility, salinity

index, effect on soil pH, effect or need for the accompanying anion of potassium, and its price per unit of potash supplied.

For strawberry, a crop sensitive to salinity and chlorine, the choice of the potassium fertilizer source must be chosen wisely.

Results of this research work indicate that with the same overall N-P-K-Mg-Ca fertilization rate in strawberry fertigation, the two potassium fertilizer sources, potassium sulfate (PS) and potassium nitrate (PN), are identical in terms of their effects on production and quality parameters of strawberries grown under fertigation.

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