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Study of Strawberry Fertilization Practices and Their Effects on Fruit Yield and Quality in the Loukkos-Gharb Region

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Abstract: The purpose of this study is to investigate the effect of strawberry fertilization practices on fruit yield and quality in the Loukkos-Gharb region in Morocco. The investigation combined a survey carried out among strawberry growers, and fruit laboratory analysis performed on strawberry samples collected from growers' farms. Our results show that cultivation practices are almost similar among growers. However, we have observed that large-scale strawberry growers prefer higher planting density, 65,000 plants/ha in average compared to 55,000 plants/ha practiced generally by the rest of the growers, and they use the Fortuna strawberry variety, an early maturing plant material. We also noticed that early planting of root ball plants of the Fortuna strawberry variety in high tunnels, at the beginning of September, allows large-scale strawberry growers to harvest at the start of November, a month earlier than the other growers. Again, such strawberry cultivation system set up in the region offers high yields for large growers, an average of 60 T/ha compared to 45 and 50T/ha obtained by small and medium growers, respectively. Fruit analysis revealed variations in soluble solids concentrations ranging from 6.7 to 11 °Brix, these values are independent of variety, category of producer and yield. For the fertilization aspect, several trends of soluble solids concentrations were correlated with three elements N, P and K showing respective correlation coefficients of 0.34, 0.35 and 0.48. Only Potassium has shown a significant correlation ($p=0.05$). No significant relationship was found between acidity and the studied nutrients.

Keywords: Strawberry, Yield, Quality, Potassium, Management, Brix, Acidity

1. Introduction

Small red berries sector is one of the most dynamic agriculture sector in Morocco, including strawberry, raspberry and blueberry, mostly located in the Loukkos and Gharb areas, representing about 75% of national production. This sector generates a turnover of more than 6 billion Dh and more than 17 million working days of which 2/3 in the farms and 1/3 in the packaging houses [1], thus contributing to the creation of employment in rural areas.

Strawberry cultivation still occupies a prominent place in the red berries sector, representing 29% of the total area of red berries in Morocco (11,400 ha) and more than 50% of Moroccan red fruit exports [1]. During the 2020-2021 crop year, strawberries production has reached 102,000 T of which 80% were exported as fresh or frozen fruit, allowing Morocco to become the 10th largest strawberry exporter in the world.

It is clear that strawberry crop occupies an important socio-economic place, however it is becoming less and less profitable with the increase in production costs (labor, pesticides and fertilizers products, ridging, plastic mulching, tunnels, greenhouses) and sales prices that do not follow this evolution, not to mention the fierce competition in the

international market that increasingly demands quality [2].

To be more competitive on the export strawberry market, it is necessary to ensure not only the quantity of fruit, but also their quality. Strawberries marketing is essentially based on quality parameters, basically sugar content (°Brix), acidity and visual appearance characteristics [3-4].

In such situation, the segmentation of the market with a quality production, and thus with high added value, would make the offer of these fruits more attractive, and would allow the strawberry growers to differentiate themselves on a more qualitative niche, in sensory and nutritional terms acceptable by the partners of the sector and the consumers.

In terms of cultivation practices, fertilization is particularly essential due to its importance in plant nutrition and the impact on fruit productivity and quality. Indeed, there is an appreciable amount of research works reporting the effect of Nitrogen (N), Phosphorus (P), Potassium (K), Calcium (Ca) and Magnesium (Mg) on growth, yield and various parameters of fruit quality in vegetable crops. Nitrogen is considered the most needed nutrient by plants since it is strongly involved in all metabolic activities of the plant; it serves as a constituent of many plant cell components, such as amino acids that make up structural proteins and enzymes important for metabolism, nucleic acids, and chlorophyll [5-7]. Moreover, it affects fruit quality parameters such as fruit total soluble solids (TSS) [8-9] and firmness [10]. On the other hand, Phosphorus (P) is one of the essential macro-elements for plant growth, it may play important roles in regulation of fruit quality due to its functions in energy transformation, carbon fixation and photosynthates transportation ensuring the normal growth and development of plants [11-12]. Moreover, Potassium (K) plays important roles in photosynthesis and sugar translocation, plant lodging tolerance, cell division and expansion for fruit development [13]. It also promotes the production of aromatic substances and improves the organoleptic quality of strawberries [14]. Potassium deficiency affects metabolism and consequently lowers nutritional quality and resistance to pests and diseases [15]. In contrast, excessive levels of this nutrient can be toxic for the crop [16]. Calcium reacts in cell signaling and plays a major role in the plant's defense responses following biotic or abiotic stress [17] and has a positive effect on fruit appearance and firmness [18]. The role of magnesium in the plant remains essential in the processes of photosynthesis, respiration, and protein synthesis [19]. According to Trejo-Téllez and Gómez-Merino [20] nutrient management of strawberry, the macronutrients (nitrogen, phosphorus, potassium, sulfur, calcium and magnesium) as well as the micronutrients (iron, boron, manganese, zinc, copper, molybdenum and nickel) play a crucial role on production and fruit quality.

The objective of this study is to investigate the effects of macronutrient fertilization (N, P, K, Ca, Mg) on strawberry yield and quality especially sugar and acidity content, through field surveys of strawberry growers in Loukkos-Gharb region and quality analysis of collected fruits.

2. Material and Methods

2.1. Site Selection and Sampling

The surveys involved 30 farms located in four strawberry growing areas in the Loukkos perimeter, a coastal region between Kenitra and Larache (Table 1).

The region has a Mediterranean climate characterized by the alternation of a wet and cool season from November to April (average winter temperature 11°) and a very hot dry season from May to October (average summer temperature 25°). The average annual rainfall is approximately 700 mm, almost all of which is concentrated between October 15 and April 15 [21].

Table 1. *Locations of the study area.*

Location	GPS point
Laouamra	35°4'1.744"N 6°5'19. 164"W
Chouafaâ	34° 56' 34.6"N 6° 10' 32.259"W
Moulay Bousselham	34° 52' 40. 832"N 6° 17' 38. 673"W
Dlalha	34°50' 54"N 6° 17' 38.673"W

The 30 sampled farms were divided into three groups according to the area allocated to strawberry: 9 large farms (>10 ha), 8 medium farms (5 to 10 ha) and 13 small farms (<5 ha).

2.2. Data Collection

Data for this study were collected from the sampled strawberry growers through questionnaires, as well as through the collection of strawberry fruit samples that were subjected to fruit quality analysis at the Crop Physiology Laboratory of the Department of Plant Production, Protection and Biotechnology-Hassan II Institute of Agronomy and Veterinary.

2.2.1. Field Surveys

The questionnaires were designed to describe the cultivation techniques, mainly fertilization practices associated with production and quality parameters. The data concerned:

1) General data: area planted with strawberries (ha), yields obtained;
2) Cultivation techniques: soil preparation, crop installation (variety, type of plants, planting date, density, type of shelter and harvesting date), fertilization (form, quantity and timing), irrigation (mode, volume, date, frequency), crop care (leaf removal, runner pruning, weeding, aeration of tunnels and phytohormones), plant protection (product, active ingredient, targeted disease, dose and timing).

2.2.2. Fruits Quality Analysis

To evaluate the effect of the fertilization practices on strawberry quality, fruits quality analyses were performed on the sampled fruits. The parameters measured were related to:

1) Sugar content (°Brix) measured by the refractometer "HI 96801, HANNA";
2) Acidity content 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 [22].

2.3. Statistical Analysis

Data collected from respondents in the field were subjected to Statistical analysis using SYSTAT software for descriptive statistics (means, standard deviations, minimum, maximum and frequency distribution for categorical variables) and JMP SAS 11 software for Pearson correlations and least squares regression.

3. Results and Discussion

The interest of this work is to highlight the main trends between fertilizing elements (N, P, K, Ca and Mg) and the studied parameters in terms of yield and quality of strawberry fruits (Sugar and acidity contents), as they do appear and exist in the region.

3.1. Strawberry Cultivation Practices

The survey data showed that the cultivation operations are almost identical among the producers except that the large growers are distinguished by a higher planting density, early planting (early September), cultivation in high tunnel, and the use of root ball for an early production about a month before the other growers. This system offers a high yield of 60 T/ha on average compared to 45 T/ha and 50 T/ha for small and medium growers respectively (Table 2). Indeed, several studies have reported that there is a significant effect of the cultivation system on strawberry yield, and have demonstrated also that high tunnels ensure a better intake of water and nutrients [23]. It has been reported that this has a positive impact on plant growth [24] and maximizes fruit size and weight [25-26] which directly affect production and yield.

Table 2. *Profiles of strawberry growers in the Loukkos-Gharb region.*

Growers category	Shelter type	Plants Type	Density (plants/ha)	Variety	Planting date	Harvest start date	Yield (T/ha)	°Brix
Large	High tunnel	Root ball	> 65,000	Fortuna Camarosa	01-15 Sept	01 Nov	> 60	8,5
	Low tunnel	Bare root	60,000	Sabrina Festival	15 Oct	15 Dèc - 01 Jan	40 to 60	8,5
Medium	Low tunnel	Root ball	60,000	Fortuna Camarosa	15 Sept	15-30 Nov	60	9
		Bare root		Sabrina Festival	15 Oct-01 Nov	15 Jan	30 to 60	9
Small	Low tunnel	Bare root	40,000 to 60,000	Camarosa Sabrina Festival	01 Nov	01 Fèv	30 to 45	9

The amount of nutrients used by each grower is either recommended by the packing houses or is a program developed by the farm manager, who in most cases is a trained technician or is fairly experienced in strawberry farming. The fertilization is provided on a daily basis and mainly through soluble fertilizers injected into the irrigation system (fertigation) and small doses as a supplement provided in foliar fertilization.

Table 3 shows that there is no difference between the three categories of producers in terms of fertilization practices. It can be seen that producers in the region do use, in average, the following formula: 1 N, 0.75 P_2O_5, 1.1 K_2O, 0.3 CaO, 0.2 MgO.

Table 3. *Fertilization Practices of strawberry growers considered in this survey (Kg/ha).*

Grower's category	N	P_2O_5	K_2O	CaO	MgO
Large	396	310	439	140	77
Medium	360	311	394	120	140
Small	398	310	429	130	70

3.2. Effect of Fertilization Practice on Strawberry Yield and Quality Parameters

According to the results obtained in our study a possible effect of nitrogen fertilization on strawberry sugar content (°Brix) but not on yield (Figure 1), however this effect is not statistically significant. Several studies have been conducted on the effect of nitrogen on fruit production and quality. Indeed, Els *et al.* [27] showed that optimizing nitrate fertilization before and during flowering influences floral initiation and thus affects fruiting. Few authors have shown that excess N causes a decrease in sugar content [28-30]. However, Miner *et al.* [31] found that soluble solids content was not affected by N treatments, but increased as the harvesting period progressed.

Figure 1 shows a possible effect of phosphate fertilization on yield and °Brix. This effect was also not found statistically significant. Phosphorus can be limiting in strawberry production because it maintains a pH around 6.5 and thus provides the best conditions for root absorption [32]. Several references have shown the positive effect of P on yield [33].

The distribution of points of calcium and magnesium according to the degree Brix and yield is very random. This result shows that in our study there is no effect of these two fertilizing elements on the parameters of production and quality studied (Figure 1). Indeed, Calcium rather plays a role in fruit firmness and cell wall structure, in addition to effects on growth and response to salinity stress [34]. Regarding magnesium, few studies have been conducted on its effect on strawberry, but its role in photosynthesis and protein synthesis processes remains essential in the plant [19].

In our study, the effect of fertilization was not detected for acidity of the sampled strawberry fruits as the distribution of points was random and did not follow any trend for the five

nutrients studied. However, we mention that many researchers have observed the influence of potassium fertilization on fruit acidity [35-37].

The effects of fertilization on strawberry quality were statistically insignificant for all nutrients (N, P, Ca and Mg) except for potassium (K). Indeed, Figure 1 shows a linear relationship of °Brix as a function of potassium fertilization. Although this effect on °Brix level is significant, the regression coefficient remains low. Notably, our results are in agreement with Vago *et al.* [38] who reported that potassium is a determinant of strawberry quality when sugar content, vitamin C content and acidity increase with potassium fertilization rate.

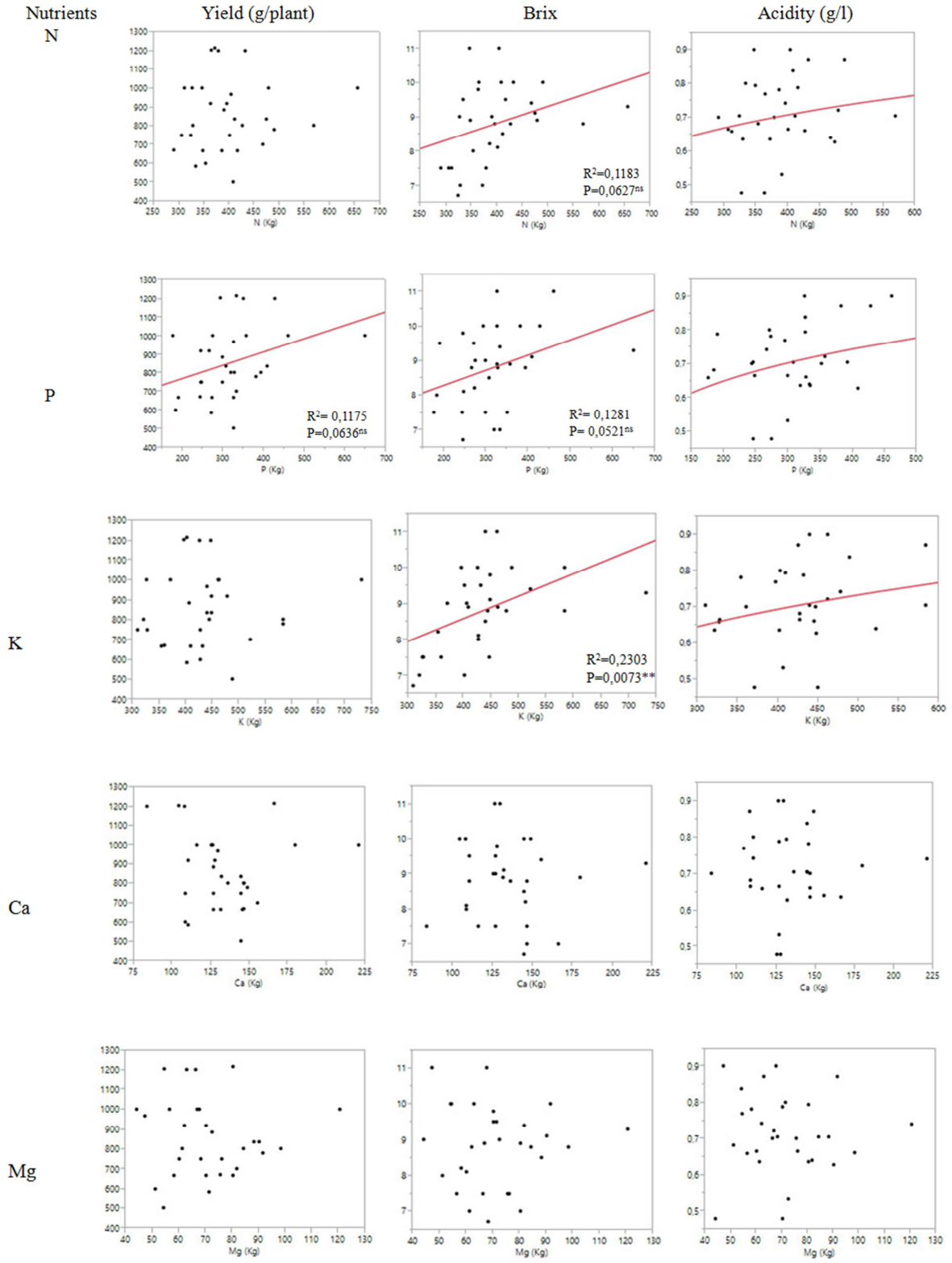

Figure 1. *Simple regression analysis of the studied parameters according to the nutrients. Stars indicate significant at p <0.01, ns: non-significant.*

A highly significant correlation is detected for °Brix with potassium fertilization (R^2= 0.48), followed by insignificant correlations with phosphorus and nitrogen fertilization with 0.36 and 0.34 respectively (Table 4). Our results are in agreement with Vago *et al.* [38] who reported that potassium is a determinant of strawberry quality when sugar, vitamin C and acidity contents increase with the potassium fertilization rate. Tagliavini *et al.* [40] and Macit *et al.* [41] also showed that Nitrogen-Potassium have a significant impact on yield and quality of strawberry fruits. Lester *et al.* [39] also established that among the many plant mineral nutrients, potassium stands out as a cation with the strongest influence on quality attributes of many plants and that soil and environmental factors often limit its uptake in amounts sufficient to meet fruit requirements during development.

Table 4. *Correlation matrix between fertilizing elements and studied parameters.*

Variables	N (Kg/ha)	P (Kg/ha)	K (Kg/ha)	Ca (Kg/ha)	Mg (Kg/ha)	Sugar content (°Brix)	Acidity content (%)	Yield (g/plant)
N (Kg/ha)	1							
P (Kg/ha)	,712**	1						
K (Kg/ha)	,897**	,707**	1					
Ca (Kg/ha)	,555**	,537**	,468**	1				
Mg (Kg/ha)	,620**	,609**	,598**	,607**	1			
Sugar content (°Brix)	,344	,358	,480**	-,031	-,015	1		
Acidity content (%)	,163	,287	,231	-,016	-,028	,458*	1	
Yield (g/plant)	,100	,343	,058	-,073	-,042	,068	-,074	1

** Correlation highly significant at the 0.01 level.
* Correlation significant at the 0.05 level.

4. Conclusion

This work has analyzed the effect of fertilization practices on strawberry yield and quality parameters in the Loukkos-Gharb region in Morocco among a group of thirty strawberry growers. The results obtained in this study, show that potassium nutrient is positively correlated with strawberry fruit quality (°Brix). Further research in the region, mainly as experimental trials, is needed to better evaluate the effect of potassium fertilization on strawberry production and quality.

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