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Effect of Phosphorus and Sulphur Fertilization on Yield and Quality of Fennel (*Foeniculum vulgare* Mill.) Grown in Sandy Soil

Adel S. El-Hassanin[1], Amira Sh. Soliman[1], Sayed T. Abou Zeid[2], Manal Mubarak[3], Reda E. Essa[4], Aida S. Ahmed[5,]*

[1]*Natural Resources Dept., Fac. African Postgraduate Studies, Cairo Univ., Egypt*
[2]*Soil Science Dept., Fac. Agric., Cairo Univ., Egypt*
[3]*Soil Science Dept., Fac.Agric, Ain Shams Univ., Egypt*
[4]*Field Crops Research Dept., National Research Centre, Dokki, Giza, Egypt*
[5]*Central Admin. of Soils, Water and Environ, Ministry of Agric. and Land Reclamation, Egypt*

Abstract

Phosphorus and Sulphur are among the most important plant nutrient for crop production and the sufficient use of P fertilizer for sustainable crop production. This study evaluated the effet of phosphorus fertilizer on the yield and quality of the fennel during the two successive seasons of 2014/2015 and 2016/ 2017 at the farm of the Faculty of Agriculture, Ain Shams Universités, Shubra El-Khaimah, El-Qalyubia, Egypt. The experiment included 10 treatments. A randomized complete block design was carried out with three replications. Phosphorus was applied at form of Single Super, Rock phosphate (RP1), (RP2) kg P/fed, Sulphur and Farmyard manure. The best results in terms of essential oil, anethole and pectin were recorded in crop fertilized with Rock phosphate (RP2) 300 kg/fed + 200 kg/fed sulphur followed by Rock phosphate (RP2) 300 kg/fed +10 ton/fed farmyard manure (FYM2), single super phosphate (SSP) 300 kg/fed, Rock phosphate (RP2) 300 kg/fed, Rock phosphate (RP1) 150 kg/fed registered the lowest parameters. All the growth parameters of fennel were significantly improved by enriched P with S application [Rock phosphate (RP2) 300 kg/fed. +200 kg/fed sulphur]. Finally, for improving yield and quality of fennel plants under sandy soil the best treatment with rock phosphate 300 kg/fed + 200 kg/fed Sulphur.

Keywords: Rock phosphate, Sulphur, Farmyard manure, Fennel, Yield, Quality

Full length article **Corresponding Author*, e-mail: aidasamir2019@gmail.com

1. Introduction

Fennel plant (*Foeniculum* vulgare *Mill.*), is a member of the Umbelliferae family and depending on the variety, can be an annual, biennial, or perennial aromatic herb. Fennel is e in worldwide, fennel has been utilized ethno botanically to cure various ailments, including gastrointestinal issues, hormonal disorders, reproductive, and respiratory diseases [1]. Fennel contains saponins, flavonoids, cardiac glycosides, steroids, triterpenes, coumarin, proteins, essential oils, and vitamins. Fennel contains pharmacological properties such as anti-inflammatory, antistress, antioxidant, anti-allergic, analgesic [2]. Additionally, one of the most herbaceous plants used as medicin, it is used as a component in medicinal and cosmetic goods. Fennel improves digestion and increases appetite. Additionally, it is used to treat obesity, nausea, menopausal symptoms and kidney stones. The plants' essential oil concentration ranges from 3 to 6% [3]. Sandy soil is naturally poor in nutrients and may suffer from different environmental conditions, which affects the growth and productivity of various plants. To decrease these problems and improve the plant's ability to withstand these harsh climatic conditions, we can use some natural compounds such as minerals, vitamins and amino acids [4]. Macronutrients are from the essential and important nutrients for plant growth and development. Phosphorus is the second major plant nutrient after nitrogen. Phosphorus plays a crucial role in the production of energy in a variety of metabolic processes. It is also a key nutrient and phosphorus compounds are required by all living organisms for cell division and formation of meristematic tissues, as well as: proteins that make up the essential components of each cell. Significant nutritional issues are brought about by phosphorus shortages in newly reclaimed soils [5]. Although rock phosphate is a natural supply of phosphorus and might be used in place of

chemical phosphate fertilizers, it is only soluble on acidic soils and cannot be utilized on alkaline soils [6]. Interest in fertilizers made of suitable organic materials and rock phosphate has recently grown. Additionally, adding organic manures in boost the soil physico-chemical characteristics and raise the amount of active organic carbon, enhancing the soil's overall quality [7]. Sulphur is the fourth major plant nutrient after nitrogen, phosphorus and potassium. Sulphur is essential for synthesis of amino acids, proteins, oils and component of vitamin A. Sulphur is also a component of key enzymes and vitamins in the plant and is necessary for the formation of chlorophyll. The need for sulphur fertilization has also been identified because of the increased use of S-free fertilizers and higher productivity of crops associated with greater uptake of sulphur. Increased use of fertilizers without sulphate and the enhanced productivity of crops linked to greater sulphate absorption have both highlighted the need for sulphur [8]. [9] observed greater fennel plant productivity with phosphorus fertilizer with high rate was used compared to the other combination treatments under same conditions. In recent years, research has been focused on enhancing the technological aspects of fennel including studies on varieties, fertilizers, irrigation, sowing dates and procedures, plant density, disease resistance and weed management especially in Egypt. The research conducted by [10] revealed that the usage of organic manure boosted all vegetative development parameters measured as plant height, leaves/plant, (fresh and dry) weight of the entire plant, total green yield, and nutrient content in leaves and bulbs (N, P and K). The addition of organic fertilizers also improved the K/Na ratio, calcium, proline, and essential oil content of leaves. [11] Demonstrated that farmyard manure plus vermin-compost (50:50) created an economically rewarding and long-lasting yield over time. The major aim of this study is to employ rock phosphate with organic and sulphur fertilizers to boost the availability of immobilized phosphate and to reduce the use of mineral fertilizers apart from increasing the productivity and quality of fennel.

2. Materials and Methods

2.1. Experimental site

Two consecutive first and second seasons of this study were conducted at 2014/2015 and 2016/2017 at the farm of the Faculty of Agriculture, Ain Shams University's, Shubra El-Khaimah, El-Qalyubia, Egypt.

2.2. Soil sampling and analysis

Before seeding, a representative soil sample (0 to 30 cm) was collected from the experimental field to evaluate its physical, chemical properties were analyzed according to [12]and [13] as shown in Tables (1), results for the chemical analysis of rock phosphate and farmyard manure are shown in Tables (2 and 3).

2.3. Experimental design

The experiment design was complete randomized design with three replicates. The 10 treatments were:

1. Control (no fertilizer)
2. Single super phosphate (SSP) 300 kg/fed
3. Rock phosphate (RP_1) 150 kg/fed
4. Rock phosphate (RP_2) 300 kg/fed
5. Rock phosphate (RP_1) 150kg/fed +Farmyard Manure (FYM_1) 5 ton/fed
6. Rock phosphate (RP_2) 300kg/fed +Farmyard Manure (FYM_1) 10 ton/fed
7. Rock phosphate (RP_1) 150 kg/fed +Farmyard Manure (FYM_2) 5 ton/fed
8. Rock phosphate (RP_2) 300 kg/fed +Farmyard Manure (FYM_2) 10 ton/fed
9. Rock phosphate (RP_1) 150 kg/fed +200 kg/fed Sulphur (S).
10. Rock phosphate (RP_2) 300 kg/fed +200 kg/fed Sulphur (S).

Nitrogen and Potassium were added at the rate of 40 kg N kg/fed and 42 kg K_2O/fed. Respectively were added as (ammonium sulfate 33.5% N, potassium sulfate 48% K_2O) and mixed thoroughly with the soil, N fertilizer was distributed in two equal doses. The first dose of N was added after 30 days sowing and the second dose was added after 45 days after. During the two growth seasons, weeds were controlled by hoeing after 40 and 60 days of seeding. Cultural practices, were applied as recommended by the Egyptian Ministry of Agriculture.

2.4. Cultural practices

Fennel seeds were sown on the 10th November in the first and second seasons on both sides of the ridge at a distance of 25 cm and a rate of 5 kg/fed (fed = 4200 m2), and thinning was done 30 days after sowing by leaving two plants in the hill. The area of the experimental is 15 m2 (1/280 fed). Five ridges measuring 5 m long and 0.7 m wide made up each plot. The seeds were obtained from the Agricultural Research Center, Department of Medicinal and Aromatic plants, Giza. After 12 days of sowing, germination was essentially finished. There was irrigation every 3–5 days.

2.5. Yield and its components

After 90 and 150 days (the end of the vegetative stage), samples were taken based on growth factors such as plant height (cm), the number of branches per plant, and the dry weight of the shoots. Plants were harvested, and the weights of seed yield characteristics were recorded in accordance with [14]. After each plant's plot was harvested, the seed and straw yield (ton/fed) were calculated by multiplying the yields per plot by 670.

2.6. Chemical analysis

For each plant (three samples), 0.5 g of powdered components were separately digested with a solution of sulphuric acid and hydrogen peroxide. The chemical content of the seeds were estimated such as oil percentage and anethole percentage was recorded according to [15].

Pectin % : The dried fennel powder (20 g) was defatted with petroleum ether (1 g: 10 ml) by placing the fennel ether mixture on a rotary shaker (120 rpm, 25 °C) for 4 hours. The fennel pectin was then extracted using a previously reported extraction process. An aqueous extraction using phosphate buffer 0.1M (1 g of powder: 30 ml of buffer solution), pH 6.0,

and 80 °C for 1 hour was performed on the defatted fennel powder. After extraction, centrifugation (3000 rpm for 10 min at 25 °C) is used to separate the soluble polymer from the insoluble residue. After being concentrated by evaporation at 80 °C, the pectin that had been solubilized in the supernatant was precipitated with 96% (v/v) aqueous ethanol at 40 °C for one hour (1:2). Following ethanol extraction, isopropanol washing and freeze-drying were done. The amount of dry fennel powder used in the extraction process and the amount of dry fennel pectin extract that was produced were used to calculate the percentage of pectin. Last but not least, the mineral content of seeds (N, P, K, and S) was calculated using [14].

2.7. Statistical Analysis

The data were statistically evaluated using analysis of variance (ANOVA), mean comparisons with COSTAT, and the least significant differences (LSD) at a level of 5% to determine differences between means. Statistical software for Windows version 6.1 was used for the calculations [16].

3. Results and discussion

3.1. Plant height and number of branches per plant

The information in figure 1 describes the fennel plant height, number of branches per plant. Fertilization rock phosphate (RP_2) 300 kg/fed+24 ton/ha farmyard manure (FYM_2), single super phosphate (SSP) 300 kg/fed, rock phosphate (RP_2) 300 kg/fed rock phosphate (RP_1) 150 kg/fed yielded the highest plant height and the number of branches per plant, respectively. It is assumed that the increase in plant height over the control treatments may be due to the increase in rock phosphate (RP). While the number of branches per plant increased in comparison to RP_1, respectively. Rock phosphate (RP_2) 300 kg/fed +200 kg/fed sulphur (S) produced the highest values of plant height and number of branches in shoots at harvest stage. In terms of the effect of fertilizer rate on plant height and the number of branches per plant, the results in figure 1 show that increasing the rate of applied RP fertilizer significantly increased plant height and the number of branches per plant, with the highest increase at the highest rate of application (300 kg/fed). Rock phosphate (RP_2) 300 kg/fed +200 kg/fed sulphur (S) produced the highest values of plant height and number of branches in shoots at harvest stage. In terms of the effect of fertilizer rate on plant height and the number of branches per plant, the results in figure 1 show that increasing the rate of applied RP fertilizer significantly increased plant height and the number of branches per plant, with the highest increase at the highest rate of application (300 kg/fed). In terms of the interaction effect of fertilizer types and rates of application on plant height and number of branches/plant of fennel, the results in figure 1 show that there were significant interactions between fertilizer type and rate of application in both seasons, with the exception of the second season on number of branches/plant at harvest, which was non-significant. Highest plant height and number of branches / plant at the greatest rate (300+200 kg/fed) in the two growth seasons. These findings are consistent with those of [9] discovered that the application of sulphur boosted the growth parameters of sorghum plants. While the study of [8] showed that phosphorus has a number of specific benefits for enhancing plant growth, chemical composition, productivity, and overall quality in various plants.

3.2. Straw and seed (ton/fed)

Data present in figure 2 demonstrate that there were significant differences due to the other types of fertilizers added with rock phosphate, rate and their interaction. The data clearly shows that all rock phosphate enhanced the seed and haulm yield over no rock phosphate application in both seasons. It is clearly evident at the harvest stage that the values of seed and haulm yield increased progressively with an increase in rock phosphate application Rock phosphate (RP_2) 300 kg/fed+200 kg/fed sulphur (S). At harvest stage, the treatments (RP_2+FYM_2), (SSP), (RP_2), and sulphur produced the maximum seed and straw or haulm yield in comparison to rock phosphate (RP_1) 150 kg/fed. The additional SSP (300 kg/fed) increased straw yield over the control treatments compared to RP_1 the increase in seed yield as for rock phosphate fertilizers rates, it is obvious from data that gradual and significant increase in seed and straw yield of fennel were registered with increase in rock phosphate rate up to 300 kg/fed. Regarding the interaction effects between rock phosphate and rates of application it is clear that (figure 2) in both seasons; they were significant on fennel seed and straw. Regarding the impact of phosphorus rate, it was shown that rising P rate led to higher concentrations of nitrogen and phosphorus from all sources. The lowest value of N and P concentration was obtained at the low rate of P, while the highest value was found at a higher rate of (RP_2 +S). According to [17], sulphur was determined to be a good product that could guarantee financial returns, enhance commercial fruit quality, and lower labour costs in the field.

3.3. Nitrogen and Phosphorus (%)

Data from figure 3 shows the differences in nitrogen and phosphorus content of fennel seeds as influenced by application of fertilizer type and rate of application. The data obviously show that all rock phosphate treatments were significantly superior significantly to control during both seasons. Data presented revealed that highest values of N and P content were found in (RP_2+S) at harvest stage. It was followed by treatments (RP_2+FYM_2), (SSP), (RP_2) and (RP_1). N and P contents (%) in the shoots increased at by harvest stage and the highest were found in treatments (RP_2+S) at harvest stage followed by, (RP_2+FYM_2), (SSP), (RP_2). The treatment (RP_1) registered the lowest values. The percentage of increase in N and P concentration recorded was highest with (RP_2+S) over the control plot. Increased NPK absorption may be related to improved seed production and increased NPK content in seed. This might also be attributable to the increased availability of nutrients in the soil as a result of application of the nutrients in adequate dose.

Table 1. Some physical and chemical characteristics of the investigated soil

Characteristics	Values
Coarse sand 2000-200µ (%)	69.4
Fine sand 200-20µ (%)	19.75
Silt 20-0µ (%)	5.6
Clay < 2µ (%)	5.25
Texture Class (%)	Sandy
Chemical Analysis	
pH 1:2:5	8.20
EC dSm^{-1}	2.30
$CaCO_3$%	1.67
OM%	0.15
Soluble cations (meg/l)	
Ca++	10.0
Mg++	3.20
Na+	10.0
K+	3.00
Soluble Anions (meg/l)	
Cl^-	12.5
HCO_3^-	10.1
CO_3^2	0.00
SO_4^2	3.60

Table 2. Chemical analyses of the rock phosphate

Characteristics (%)	**Value**
EC dS.m^{-1}	2.66
pH (1: 5)	7.43
Moisture content (%)	36.50
Organic matter(%)	46.61
Organic carbon (%)	31.80
C:N ratio	16.14
(Available nutrients) (ppm)	**Value**
N	0.03
P	83.00
K	105.00
Fe	18.30
Mn	15.60
Zn	8.90
Cu	2.40

Table 3. Chemical analysis of farmyard manure

Characteristics	**(%)**	**Characteristics**	**(%)**
H_2O	3.10	SiO_2	11.81
Organic matter	0.61	SO_3^{--}	1.66
P_2O_5	26.01	Na_2O	0.33
K_2O	0.03	Fe_2O_3	2.54
CaO	45.10	AL_2O_3	0.51
MgO	0.60	CO_2	7.50

Table 4. Effect of investigated treatments on Plant height (cm) and Number of branches/ plant of Fennel plant at different growth stages during two successive seasons (2014/2017)

Treatments		Plant height (cm)				No. of branches/plant			
		1st		2nd		1st		2nd	
Control		Veg.	Harv.	Veg.	Harv.	Veg.	Harv.	Veg.	Harv.
SSP		15.57	19.27	16.47	21.70	1.17	1.17	1.27	1.27
RP_1		30.90	34.97	32.63	35.87	1.57	1.57	1.60	3.23
RP_2		26.57	30.17	27.13	30.57	1.53	1.53	1.50	3.00
RP_1+ FYM_1		32.37	33.47	31.97	33.93	1.63	1.63	1.60	3.20
RP_2+FYM_1		34.23	37.97	35.87	39.30	1.80	1.90	1.90	3.60
P_1 R+FYM_2		35.43	39.73	36.93	40.90	2.00	2.00	2.30	3.80
RP_2 +FYM_2		36.20	42.27	38.27	43.10	2.17	2.17	2.50	4.10
RP_1 + S		39.30	46.20	41.23	47.07	2.80	2.80	2.77	4.63
RP_2 + S		41.43	48.30	43.37	49.47	2.97	2.97	3.17	4.77
LSD 0.05	Fert.	1.24	0.90	0.37	1.14	0.08	0.09	0.07	0.28
	Rate	0.44	0.16	0.13	0.20	0.02	0.03	0.02	0.07
	Fert.*Rate	1.23	0.46	0.37	0.57	0.05	0.09	0.06	ns

Veg. : Vegetative Stage Harv.: Harvest Stage

Table 5. Effect of investigated treatments on Straw yield (ton/fed) and Seed yield (ton/fed) of Fennel plant at different growth stages during two successive seasons (2014/2017)

Treatments		Straw yield (ton/fed)		Seed yield (ton/fed)	
		1st	2nd	1st	2nd
Control		0.32	0.36	1.01	1.02
SSP		0.76	0.78	1.15	1.16
RP_1		0.70	0.71	1.14	1.13
RP_2		0.73	0.75	1.13	1.13
RP_1+ FYM_1		0.81	0.82	1.16	1.17
RP_2+FYM_1		0.85	0.87	1.19	1.20
RP_1 +FYM_2		0.86	0.87	1.21	1.22
RP_2 +FYM_2		0.89	0.90	1.23	1.25
RP_1 + S		0.92	0.93	1.36	1.38
RP_2 + S		0.94	0.95	1.40	1.41
LSD 0.05	Fert.	0.012	0.014	0.005	0.005
	Rate	0.002	0.003	0.002	0.002
	Fert.*Rate	0.007	0.009	0.006	0.007

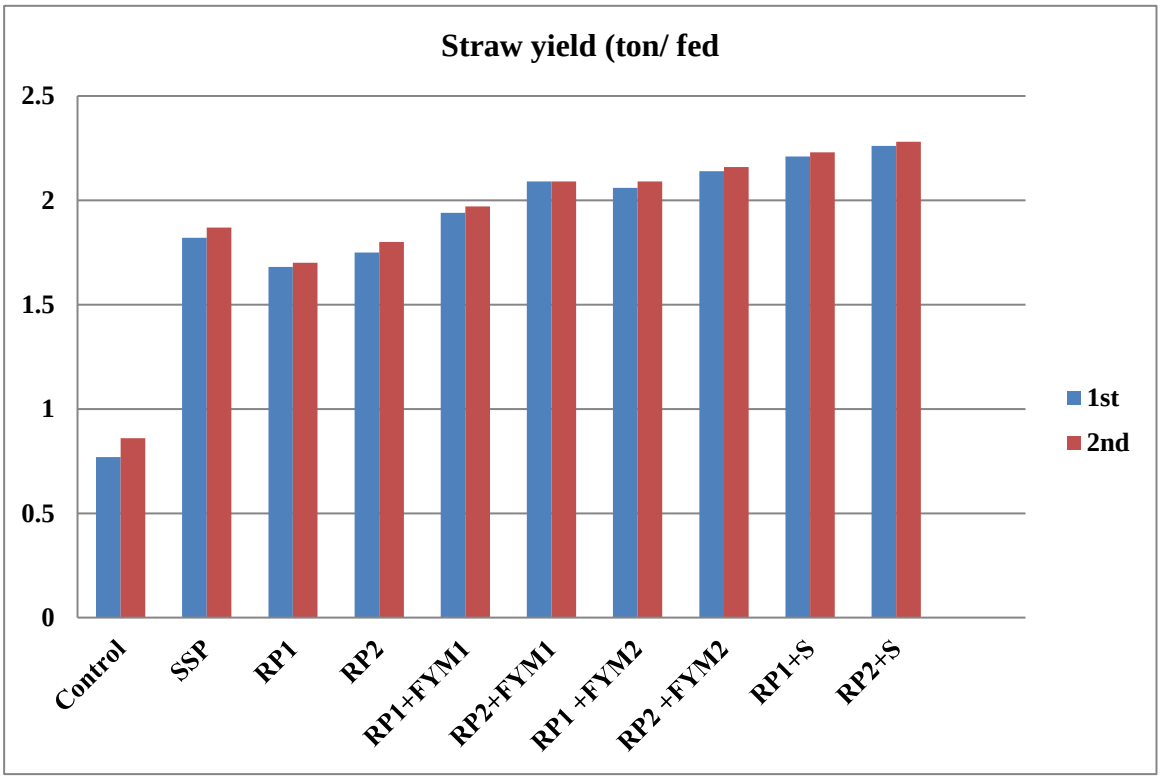

Figure 1. Effect of treatments on straw yield (ton/fed) of fennel plant during two successive seasons

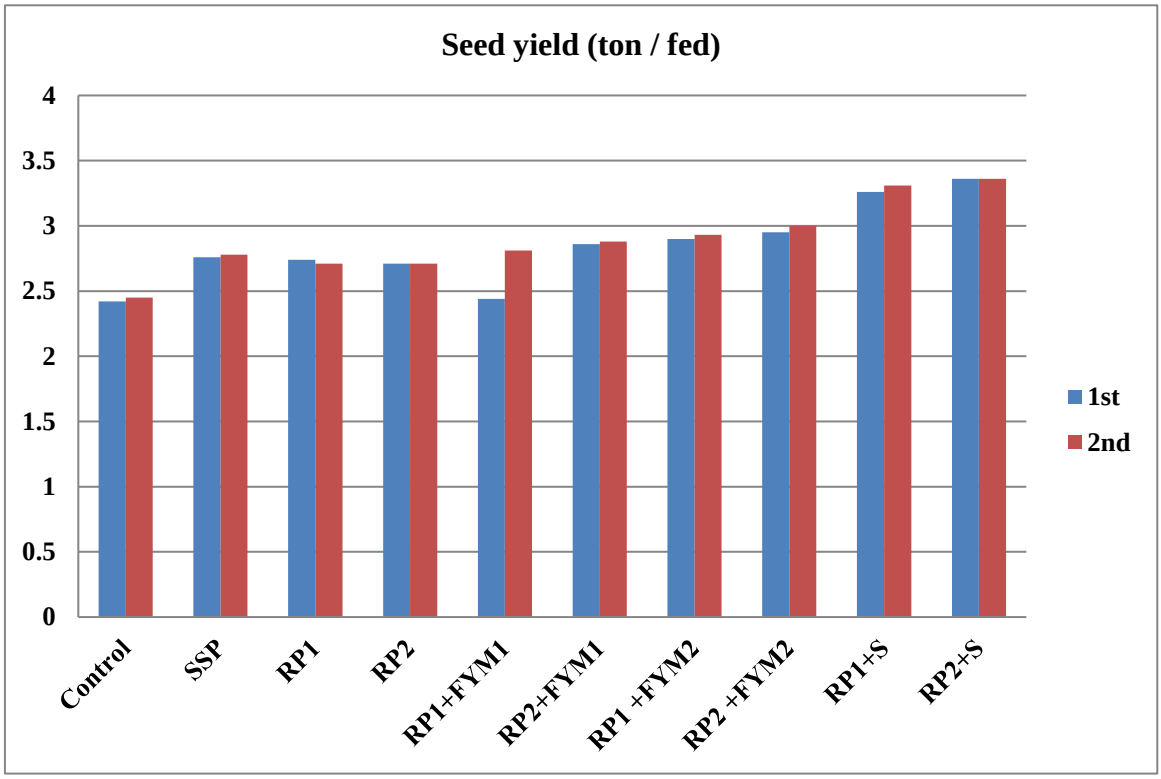

Figure 2. Effect of treatments on seed yield (ton/fed) of fennel plant during two successive seasons.

Table 6. Effect of investigated treatments on Nitrogen (%) and Phosphorus (%) of Fennel plant at different growth stages during two successive seasons (2014/2017)

Treatments		Nitrogen (%)				Phosphorus (%)			
		1st		2nd		1st		2nd	
		Veg.	Harv.	Veg.	Harv.	Veg.	Harv.	Veg.	Harv.
Control		1.22	1.30	1.24	1.32	0.10	0.11	0.12	0.13
SSP		1.85	1.87	1.89	1.94	0.27	0.29	0.28	0.28
RP_1		1.75	1.78	1.79	1.82	0.18	0.19	0.18	0.19
RP_2		1.80	1.85	1.83	1.88	0.20	0.21	0.21	0.21
RP_1+ FYM_1		1.80	1.82	1.83	1.85	0.22	0.21	0.20	0.20
RP_2+FYM_1		1.85	1.88	1.88	1.91	0.24	0.25	0.24	0.25
RP_1 +FYM_2		1.90	1.91	1.94	1.96	0.21	0.23	0.24	0.26
RP_2 +FYM_2		1.95	1.98	1.99	2.02	0.27	0.28	0.26	0.26
RP_1 + S		2.51	2.67	2.55	2.73	0.29	0.30	0.29	0.30
RP_2 + S		2.65	2.77	2.69	2.83	0.29	0.31	0.30	0.30
LSD 0.05	**Fert.**	0.02	0.04	0.003	0.03	0.01	0.02	0.011	0.011
	Rate	0.006	0.007	0.012	0.012	0.007	0.004	0.005	0.002
	Fert.*Rate	0.006	0.02	0.002	0.011	0.02	0.01	0.016	0.007

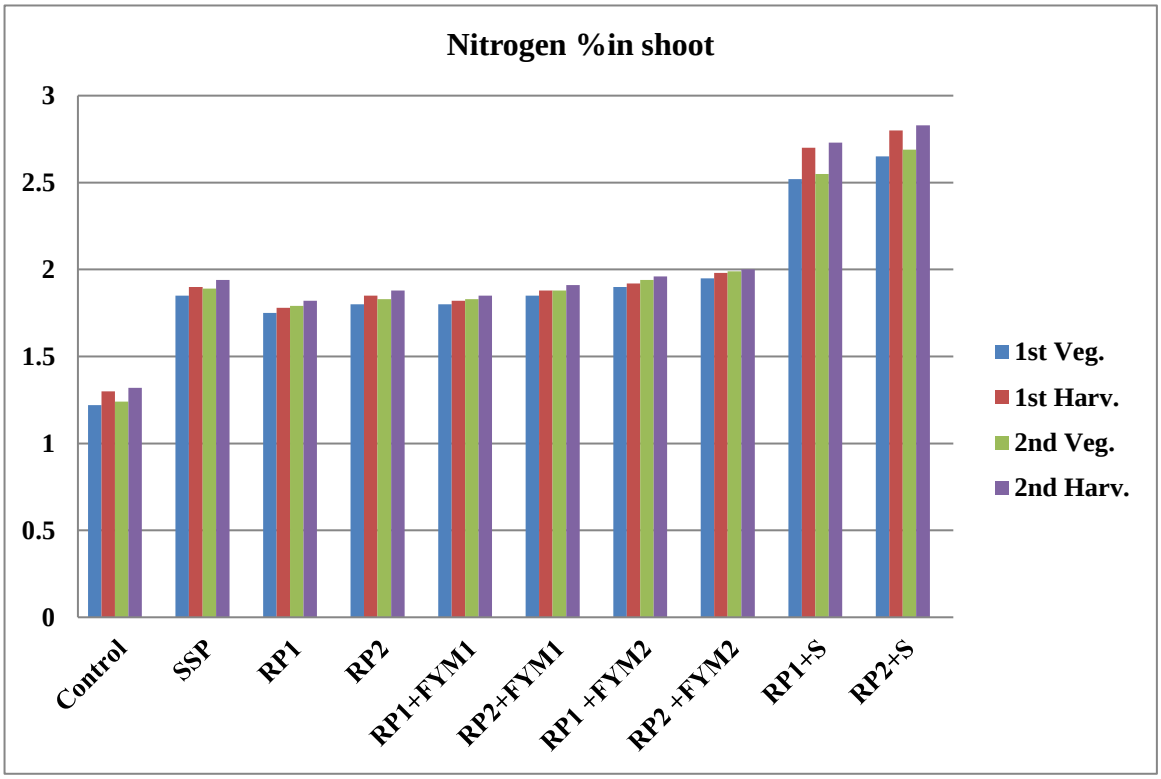

Figure 3. Effect of treatments on nitrogen (%) of fennel plant at different growth stages during two successive seasons.

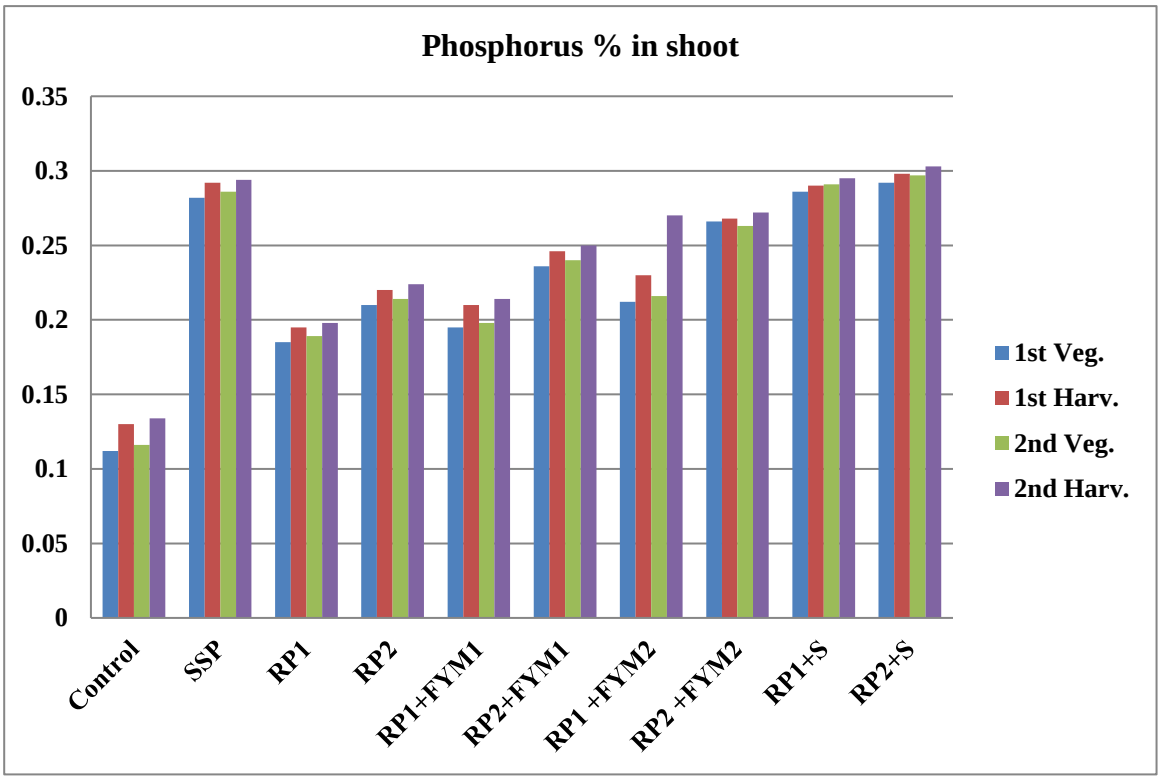

Figure 4. Effect of treatments on phosphorus (%) of fennel plant at different growth stages during two successive seasons.

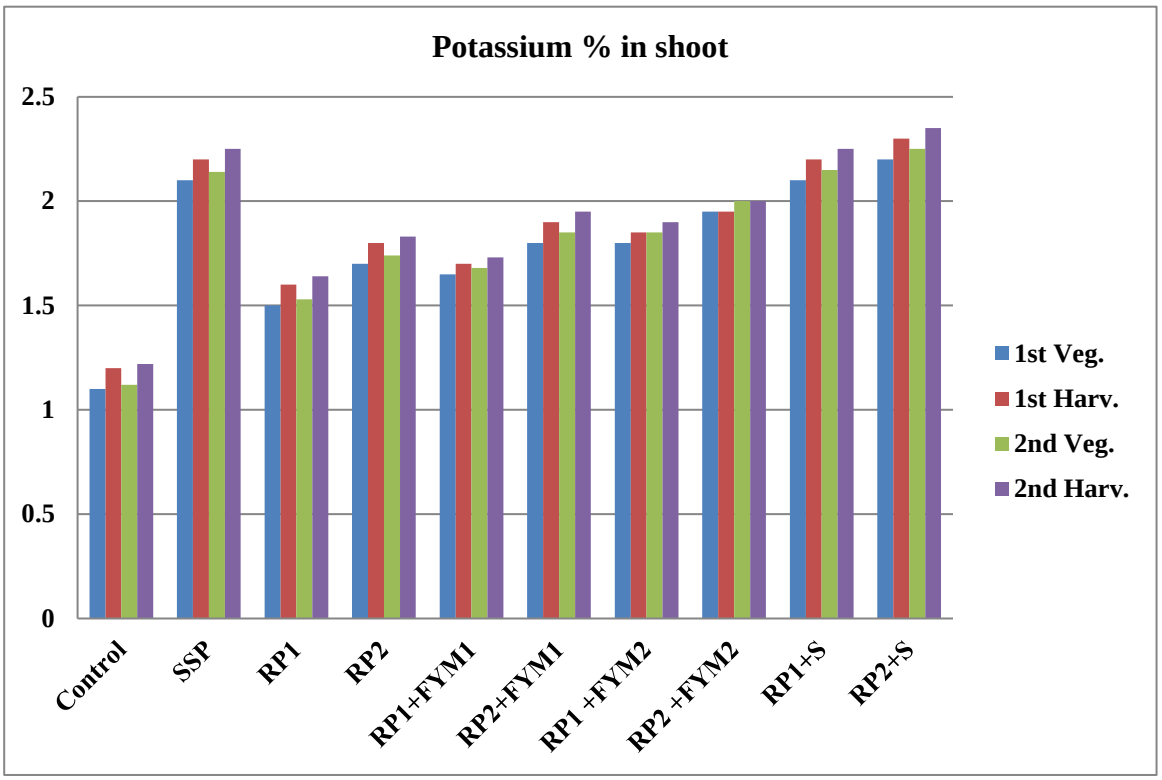

Figure 5. The effect of the treatments on potassium (%) of fennel of fennel plant different growth stages during two successive seasons.

Table 7. Effect of investigated treatments on Potassium (%) and Sulphur (%) of Fennel plant at different growth stages during two successive seasons (2014/2017)

Treatments		Potassium (%)				Sulphur (%)			
		1st		2nd		1st		2nd	
		Veg.	Harv.	Veg.	Harv.	Veg.	Harv.	Veg.	Harv.
Control		1.03	1.10	1.12	1.13	0.12	0.11	0.13	0.11
SSP		2.20	2.10	2.25	2.14	0.40	0.35	0.41	0.36
RP_1		1.53	1.43	1.64	1.53	0.20	0.15	0.21	0.16
RP_2		1.73	1.70	1.83	1.74	0.25	0.18	0.26	0.81
RP_1+ FYM_1		1.67	1.65	1.73	1.68	0.22	0.20	0.24	0.22
RP_2+FYM_1		1.88	1.81	1.95	1.85	0.28	0.26	0.30	0.27
RP_1 +FYM_2		1.85	1.81	1.91	1.85	0.24	0.25	0.25	0.26
RP_2 +FYM_2		1.95	1.96	2.00	2.00	0.30	0.28	0.31	0.29
RP_1 + S		2.23	2.17	2.25	2.15	0.35	0.30	0.37	0.32
RP_2 + S		2.30	2.23	2.31	2.25	0.40	0.35	0.42	0.37
LSD 0.05	**Fert.**	0.10	0.09	0.03	0.03	0.009	0.007	0.005	0.31
	Rate	0.02	0.01	0.02	0.01	0.001	0.008	0.001	0.15
	Fert.*Rate	0.04	0.05	0.05	0.04	0.002	0.009	0.004	ns

Table 8. Effect of investigated treatments on oil, anethole and pectin (%) in seeds of fennel plant at different growth stages during two successive seasons (2014/2017)

Treatments	Oil (%)	Anethole (%)	Pectin (%)

		1st	2nd	1st	2nd	1st	2nd
Control		1.04	1.07	39.37	38.27	10.50	11.20
SSP		1.57	1.55	69.27	68.37	15.20	15.00
RP_1		1.31	1.30	52.57	52.27	13.73	13.50
RP_2		1.36	1.35	58.27	56.23	13.60	13.70
RP_1+ FYM_1		1.43	1.42	65.30	64.27	15.10	14.80
RP_2+FYM_1		1.49	1.48	66.13	66.23	15.27	15.20
RP_1 +FYM_2		1.48	1.46	66.87	66.67	15.80	15.60
RP_2 +FYM_2		1.53	1.50	68.27	67.47	16.60	16.50
RP_1 + S		1.55	1.55	73.60	72.60	17.30	17.20
RP_2 + S		1.59	1.58	74.80	74.30	17.90	17.80
LSD 0.05	**Fert.**	0.02	0.02	0.10	0.11	0.34	0.36
	Rate	0.005	0.003	0.02	0.02	0.09	0.09
	Fert.*Rate	0.01	0.009	0.04	0.06	0.26	0.27

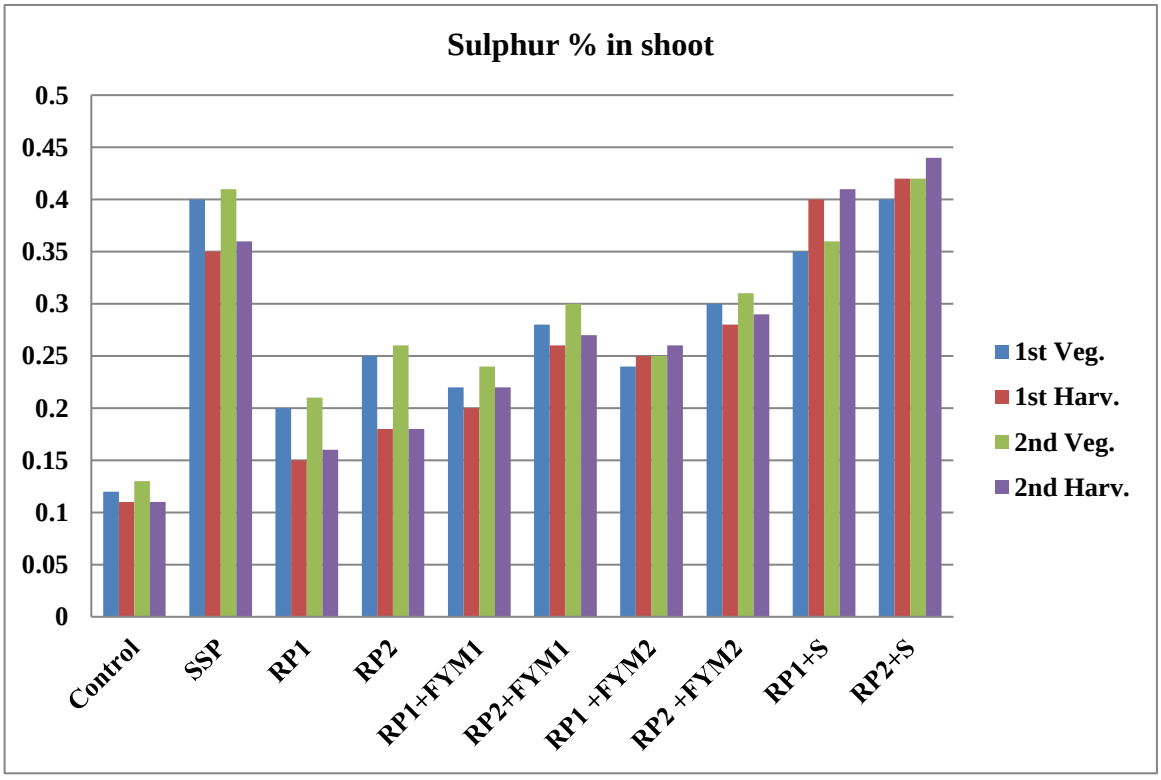

Figure 6. The effect of the treatments on d sulphur (%) plant different growth stages during two successive seasons.

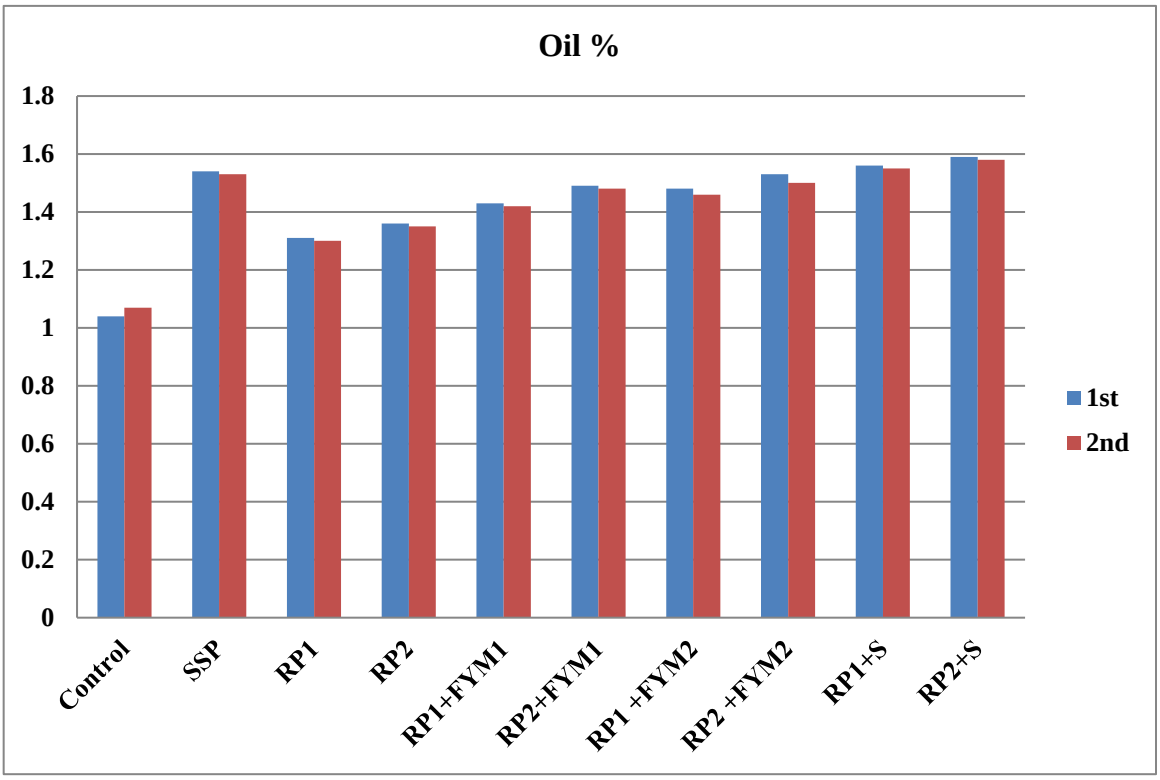

Figure 7. Effect of treatments on Oil % in Seeds of Fennel plant at harvest stage during two seasons

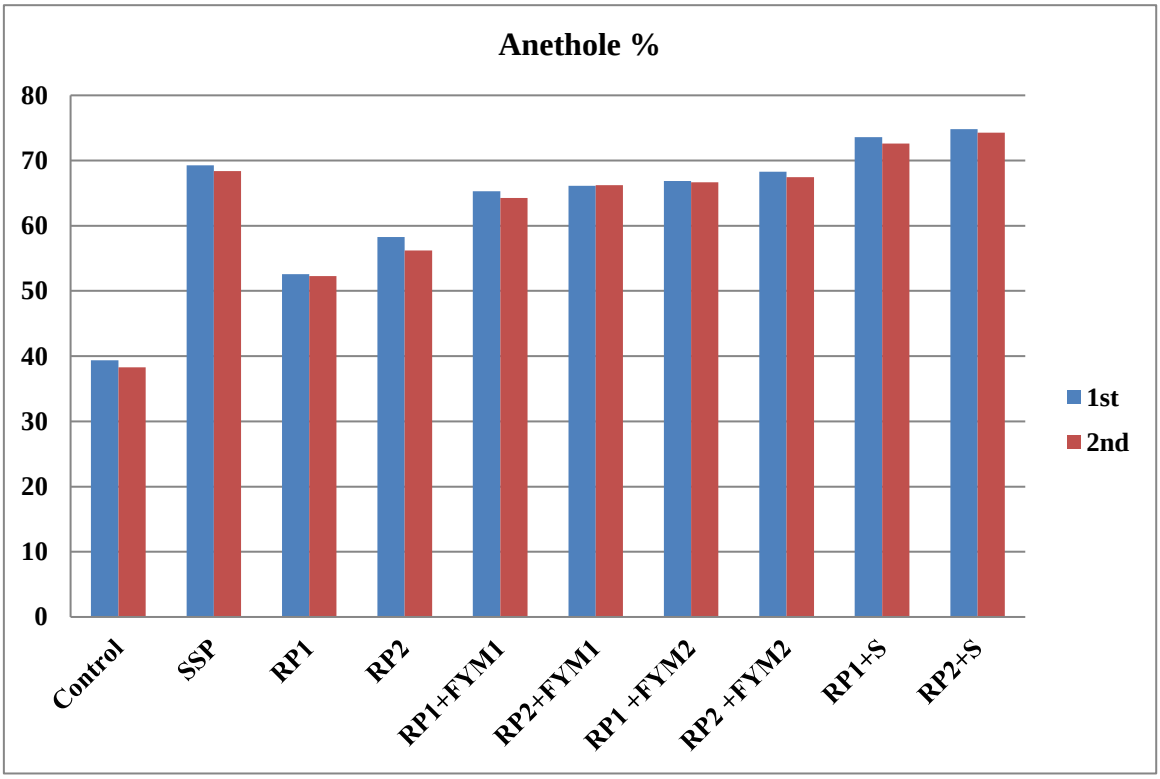

Figure 8. Effect of treatments on Anethole % in Seeds of Fennel plant at harvest stage during two seasons.

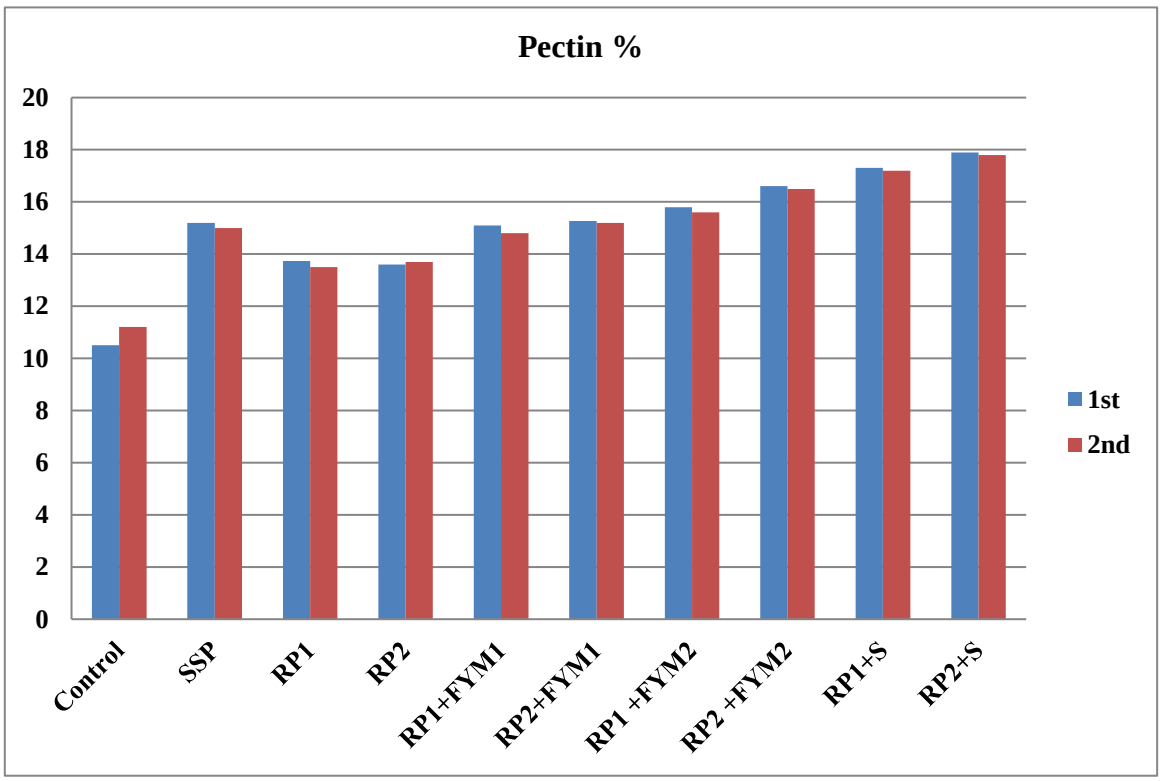

Figure 9. Effect of treatments on Pectin % in Seeds of Fennel plant at harvest stage during two seasons.

In terms of the effect of interaction between rock phosphate and application rates on nitrogen and phosphorus content in fennel (figure 3) highest applied RP2+S at (300+200 kg/fed), followed by RP_2+FYM_2, SSP, RP_2. The findings support the findings of [18] who showed that phosphorus with sulphur has the potential to boost nutrient availability and, as a result, anise output.

3.4. Potassium and sulphur (%)

Different types and rates of fertilizer application in both seasons had a substantial impact on the content of potassium and sulphur in the vegetative and harvest of the fennel plant. The greatest values were registered recorded by the treatments in the order of (RP_2+S), (RP_2+FYM_2), (SSP), (RP_2), and then (RP_1) (figure 4). The lowest potassium and sulphur concentration at vegetative and harvest stages was found with treatments (RP_1) and control in both seasons, respectively. With respect to interaction between the fertilizer types and rates data (figure 4) apparently indicate significant effects on potassium and sulphur concentrations in both seasons, except for the second season of sulphur % at harvest was non-significant. Higher concentration of NPK in seed and straw may be due to improvement in NPK uptake as a result of adequate application of fertilizers. These findings are consistent with those of [19].

3.5. Quality Parameters

3.5.1. Oil, anethole and pectin (%) in seeds

It is evident from at (figure 5) that all the rock phosphate treatments and organic fertilizer significantly augmented oil, anethole and pectin percentage in fennel seeds in both seasons. Results also indicate that seeds of fennel plants fertilized with RP_2+S significantly exceeded (RP_2+FYM_2), (SSP), (RP_2) and (RP_1) in terms of quality parameters in both seasons over control plots. Regarding rate of rock phosphate fertilizer application progressive increase in oil, anethole and pectin content were observed with corresponding increase in phosphorus and sulphur rate up to (300 +200) kg/fed. The interaction effect was also significant on quality parameters in both seasons. The highest oil, anethole and pectin content were recorded with treatment RP2+S (300 +200 kg/fed). These results are in line with those obtained by [20] who reported that, the impact of nutrients such as nitrogen and phosphorus on the synthesis of essential oil in crop fennel. The major ingredient of fennel essential oil is anethole [21]. These findings are consistent with those of [22, 18].

4. Conclusions

This light of the finding of two years, research in works, it can be concluding that fennel plant responded significantly to add rock phosphate such as 300 kg/fed + 200 kg/fed Sulphur. Improved the solubility of RP which causes

a significant increase in P, nutritional status, yield, yield components and quality of fennel.

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