Impact of Potassium Silicate Application and Pattern on Yield and Quality of Cowpea under Fertigation

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ABSTRACT
Background and Objective: Sustainable production of quality legumes forage in sufficient quantities constitutes one of the greatest challenges facing breeders and producers. Two field experiments were performed during the two summer seasons of 2019 and 2020 in Wadi El-Natroun, El-Behaira Governorate, Egypt to study the effect of potassium silicate application and pattern of use on yield and quality of cowpea grown under sandy soil condition. Methodology: Each experiment is laid out in split-plot design with three replications. Four potassium rates were distributed in the main plot while pattern of potassium use were performed in the sub plots. Results: The obtained results showed that potassium silicate application on combined with pattern of use increase yield components as well as macronutrient uptake of cowpea grains. Conclusion: From the obtained results, it was revealed that potassium silicate is of great important for cowpea fertilization and its effect highly reflected by 5 L/fed with month of pattern.

Keywords: Potassium silicate, Pattern, Cowpea yield, Nutrient uptake

1. Introduction
Cowpea (Vigna unguiculata L. Walp.) is a large high protein food legume that is used in human and feed (Agbicodo et al., 2009). Cowpea is an important legume, especially in the hot, dry and subtropics. It is a highly nutritious especially high protein content (25%), fat 1.9%, fiber 6.3%, carbohydrate 63.6 (Ogbonnaya et al., 2003 and Agbicodo et al., 2009). Cowpea has also multi-purpose crop, used as a leafy vegetable and grain legume. It is a crop of excellent quality for fattening sheep and cattle and is considered a good feed for milking cows. In addition, cowpea has the ability to maintain soil fertility thanks to its excellent ability to fix atmospheric nitrogen.

Cowpea is suitable for Egyptian summer environmental conditions. The total cultivated area of this crop in Egypt was estimated by about 9155 fed for dry seed production in the year of 2008 with a mean production of 980 kg/fed. The Elementary silicon (Si), after oxygen, is the second most abundant element of the earthly crust (Sahebi et al., 2015). Silicon is not considered essential for plant growth and development, however, increasing evidence in the literature shows that this metalloid is beneficial to plants. It is an essential element of high-yield vegetable species such as rice, sugarcane, cereals, legumes, vegetables, tree crops and some hardwood ornaments and many species of plants. Silicon offers a number of nutritional benefits of important plants, including structural components of plant cells, including grass, rice and small grains. It is well known in crops in the field only silicon affects plant growth and quality, photosynthesis, transpiration and improving plant resistance to stresses..

The positive effect of silicon on quality and quantity may be induced by the effect of ethylene in decreasing time of aging and death. The high content of chlorophyll as a result of silicon application keep the plant healthy and in good appearance (Balakhnina and Borkowska 2013). Silicon, as a
fertilizer, organic or protective stimulating of the plant, plays a central role in improving plant growth and productivity, particularly in stress regimes (Sawas and Ntatsi, 2015).

Silicon can be observed in limiting levels under certain growth conditions (Marafon and Endres, 2013) reported that silicon may be present in small quantities in some stages of growth. Such effect may result in symptoms of micro nutrient deficiency and, in turn enhance fall time of post harvest (Sacala, 2009 and Janislampi, 2012). Therefore, silicon recently recognized as an advantageous plant nutrient and many producers already include in their crop fertility programs.

Thus, this work aimed to study the more effective rate and pattern of potassium silicate application on yield and quality forage cowpea.

2. Material and Methods

2.1. Experimental Site

Two field experiences were conducted during the 2019 and 2020 summer season in Wadi El-Natroun, El-Behaira, Egypt to study the effect of the application of potassium silicate and pattern on the yield and quality of cowpea grown in sandy soil conditions.

2.2. Soil Sample and Analysis

A representative soil sample (0-30) was taken from the experimental field before sowing each season to determine the physical and chemical characteristics. Table (1, 2) represents the physical and chemical properties of the soil and chemical analysis of irrigation water according to Klute method (1982).

Table 1: Physical and chemical properties of the experimental site before sowing.

| Particle size distribution (%) | Chemical analysis | NPK (mg/kg) |
|-------------------------------|-------------------|-------------|
| Clay                          | pH (1:2.5) Soil   | N           |
| Silt                          | EC dSm⁻¹ (1:5)    | P           |
| Fine sand                     | CaCO₃ (%)         | K           |
| Coarse sand                   | O.M (%)           |             |
| Texture class                 | Sandy             |             |

| pH | dSm⁻¹ | K⁺ | Na⁺ | Mg²⁺ | Ca²⁺ | CO₃⁻² | HCO₃⁻ | Cl⁻ | SO₄²⁻ |
|----|-------|----|-----|------|------|-------|-------|-----|-------|
| 7.82 | 0.80 | 2.20 | 4.12 | 5.40 | 7.20 | 0.00 | 4.90 | 0.60 | 13.42 |

Table 2: Chemical analysis of irrigation water used.

2.3. Experimental design

The design of this experiment is split plot design and three replicates. Four rates of potassium lay out in the main plot and three patterns of application were devoted to sub-plot.

2.4. Cultural practices

Grains of cowpea (Jumah-3) in the rate of 30 kg/fed (fed =4200 m²) were sown in mid of May in both seasons. Plots were with size of 15m² with 5 ridges (5 m long and 0.7 m wide) and the grains were sown in hills 15 cm apart. At thinning two plants/ hill was left. Cowpea variety was obtained from Feed Research Department, Feed Research Institute, Agricultural Research Centre, Egypt.

Recommended rates of nitrogen were added at the rate of 65 kg N/fed as Ammonium Nitrate (33.5% N) in three equal doses starting after thinning and ten days intervals. Phosphorus was added at the rate of 30 kg P₂O₅/fed as Calcium super phosphate fertilizer (15.5 % P₂O₅) pre-sowing. In both seasons drip irrigation system was conducted with the rate of 2 L/hour at intervals 3-4 days.

Potassium silicate (K₂SiO₃) (10% K₂O and 25% SiO₂) Potassium silicate (K₂SiO₃) (10% K₂O and 25% SiO₂) is product of industry of Ghanema Company for Fertilizers and Chemical Industries. Four rates of potassium silicate were added to water irrigation after 45 days from sowing and used in the rate of 0.0, 5, 10 and 20 L/fed. Pattern of potassium silicate application was as follows: A week, 2weeks and month.
2.6. Yield and its components

At harvest time, ten random guarded plants representing each treatment were used to determine content of total nitrogen and soluble carbohydrate in the grains on the basis of plot size grain yield, straw yield and biological yield (ton/fed.) were estimated as well as harvest index.

2.7. Chemical analysis

Grains content of total nitrogen and soluble carbohydrate was estimated according to AOAC (1982) and crude protein by multiplying the N % by 6.25 factors (Magomya et al., 2014). Phosphorus content estimated spectrophotometrically according to Carter and Gregorich (2008) method. The K+ concentrations were determined by an emission flame photometer as described by Motsara and Roy (2008).

2.8. Statistical analyses

Statistical analyses were performed according to Snedcor and Cochran (1982) and comparison between treatments mean conducted by LSD test .Combined analysis of both seasons was performed according to Steel and Torrie (1980). Bartlet’s equation was used also to estimate homogeneity test.

3. Results and Discussion

3.1. Effect of rate of potassium silicate on yield and quality of cowpea plants

Data presented in Table (3) show that potassium silicate application significantly increased grains, straw, biological yield as well as harvest index as compared with control plants regardless of the rates of silicate, while low record obtained by untreated cowpea plants. These results confirmed by Mali and Aery (2009) who indicate a beneficial effect of silicon on cowpea plants. Bakhat (2012) and Pati et al., (2016), also showed that application of silicon significantly increased grain and straw yield as well as yield-attributing parameters. Such effect of silicon on yield may be attributed to its positive effect on increasing germination (Acikbas and Ozyazici, 2021).

They also added that silicon ameliorates the vigour of plants and improves their resistance to exogenous stresses. In addition, Pilon et al., (2013) has hypothesized that the effect of silicon supply on plants contributes to improve mineral nutrition and photosynthesis parameters as well as growth under well-watered conditions.

It is worthy to note that the highest records of grain, straw, biological yield and harvest index obtained by plants treated with the lowest rate of potassium silicate (5 L/fed) (Table 3). Such effect supported by findings of Mali and Aery (2009) who reported that lower applications of silicon resulted in an enhancement in relative yield, leaf area, chlorophyll and observed a significant (P = 0.01) direct relationship between relative yield and lower applied silicon concentrations. They also indicate a beneficial effect of silicon on cowpea plants.

The data pertaining the effect of different rates of potassium silicate application under fertigation on the chemical contents of the grains are presented in Table (2). It is clearly noticed that potassium silicate application significantly increased both phosphorus and potassium irrespective of silicate rates. The same table also show that the highest grain content of phosphorus gained at 10 L/fed of potassium silicate.

These results were in conformity with the findings of Bakhat (2012) and Pati et al (2016) who reported that nitrogen (N), phosphorus (P), and potassium (K) in grain and straw were also greater under Silicon fertilization. Such promoting effect of silicon on phosphorus may be attributed to increasing availability of phosphorus by silicon fertilization (Sahebi et al., 2015). Ali et al., (2016), also found that the application (1 mM) of silicon optimizing the P N performance. The enhancing effect of silicon on potassium uptake may be resulted from the positive response of silicon application towards potassium can be linked to silicification of cell wall (Singh et al., 2006)

Concerning the effect of silicon fertilization on protein and carbohydrate content of cowpea grains, it is clearly obvious that silicate fertilization greatly increased both protein and carbohydrate content and the highest record obtained by 5 L/fed of potassium silicate (Table 3). In support of our findings, Gong and Chen (2012) and Guntzer et al., (2012) reported that such promoting effect of silicon on protein and carbohydrate content may be attributed to the enhancing effect of silicate on photosynthesis.
rate, stomatal conductance, nodulation, N₂ fixation, nutrients contents (especially N and P), chlorophyll, total soluble sugars, total soluble protein.

Table 3: Effect of different rates of potassium silicate application on yield and quality of cowpea plants

| Potassium rate (L/fed) | Grain yield (ton/fed) | Straw yield (ton/fed) | biological yield (ton/fed) | Harvest yield (ton/fed) | Harvest Index (%) | Phosphorus (ton/fed) | Potassium (ton/fed) | Protein (ton/fed) | T. Carb. (ton/fed) |
|-----------------------|----------------------|----------------------|---------------------------|------------------------|------------------|-------------------|-------------------|------------------|------------------|
| Control               | 0.69                 | 3.64                 | 4.33                      | 15.77                  | 0.49             | 1.80              | 17.70             | 39.67            |
| 5                     | 1.05                 | 4.19                 | 5.24                      | 19.90                  | 0.55             | 2.25              | 23.50             | 52.89            |
| 10                    | 0.90                 | 4.02                 | 4.93                      | 18.26                  | 0.71             | 2.02              | 19.38             | 43.61            |
| 20                    | 0.95                 | 4.09                 | 5.05                      | 18.78                  | 0.58             | 2.11              | 22.41             | 50.44            |
| LSD 0.05              | 0.02                 | 0.08                 | 0.082                     | 0.55                   | 0.06             | 0.04              | 0.69              | 1.39             |

T. Carb. = Total Carbohydrates

3.2. Effect of pattern of potassium application on yield and quality of cowpea plants

Results of mean comparison of data (Table 4) of the studied treatments showed that the response of cowpea plants to silicon application was varied owing to variation of its application. The pattern of potassium silicate significantly affect yield and yield attributes of cowpea plants.

The obtained data show that the highest grain yield and biological yield obtained by pattern of potassium silicate application once during one month. Such effect may be probably due to better and continuous availability of silicon under this treatment (Singh et al., 2005). Balakhnina and Borkowska (2013) added that potassium silicate resulted in good effect on plants chlorophyll content and help plants to maintain over a longer period with better shelf life and appearance.

As regards nutrient contents of cowpea grains, the same table (Table 4) once again show that Pattern of potassium silicate application (during month) increased grain content of potassium, protein and carbohydrate content. However, no difference effect on phosphorus content was observed.

Table 4: Effect of pattern of potassium silicate application on yield and quality of cowpea plants

| Pattern | Grain yield (ton/fed) | Straw yield (ton/fed) | biological yield (ton/fed) | Harvest yield (ton/fed) | Harvest Index (%) | Phosphorus (ton/fed) | Potassium (ton/fed) | Protein (ton/fed) | T. Carb. (ton/fed) |
|---------|----------------------|----------------------|---------------------------|------------------------|------------------|-------------------|-------------------|------------------|------------------|
| P₁      | 0.83                 | 3.78                 | 4.61                      | 17.83                  | 0.59             | 1.95              | 19.29             | 43.37            |
| P₂      | 0.91                 | 3.95                 | 4.86                      | 18.45                  | 0.57             | 2.05              | 20.80             | 46.78            |
| P₃      | 0.96                 | 4.23                 | 5.18                      | 18.24                  | 0.59             | 2.13              | 22.15             | 49.82            |
| LSD 0.05| 0.01                 | 0.11                 | 0.045                     | 0.27                   | 0.04             | 0.02              | 0.45              | 1.02             |

P₁: one week P₂: g two weeks P₃: one month, T. Carb. = Total Carbohydrates

3.3. Effect of interaction of rate and pattern of potassium silicate application on yield and quality of cowpea plants

According to the data presented in Table (5) it is clearly indicate that interaction of rate and pattern of potassium silicate has significant effect on grain, straw and biological yield as well as harvest index.

By examining data in Table (4), it is obvious that the highest record of grain, straw and biological yield (1.13, 4.65 and 5.78 ton/fed) respectively, was obtained by cowpea plants treated with potassium silicate at rate of 5 L/fed and pattern use of month after 45 days from sowing. Examined Data in Table (5) also show that interaction effect of rate of potassium silicate and pattern on grain contents of phosphorus and potassium resulted in significant increase as compared with control. It is clearly noticed that the highest phosphorus content recorded by plants supplied with potassium silicate at rate of 10 L/fed while that of potassium at rate of 5 L/fed irrespective to pattern application mode. Such effect resulted basically to the effect of silicon on phosphorus and potassium uptake. In this concern, Abdalla (2011); Bakhat (2012) and Cuongi et al., (2017) reported that the uptake of P was greater with higher dose of silicon. Singh et al., (2005) reported that application of silicon increased K uptake in rice.
Table 5: Effect of interaction of rate and pattern of potassium silicate application on yield and quality of cowpea

| Potassium rate (L/fed) | Pattern | Grain yield (ton/fed) | Straw yield (ton/fed) | biological yield | Harvest Index | Phosphorus (%) | Potassium (%) | Protein (%) | T. Carb. (%) |
|------------------------|---------|-----------------------|----------------------|------------------|--------------|----------------|---------------|-------------|--------------|
| Control                | P₁      | 0.69                  | 3.64                 | 4.33             | 15.77        | 0.49           | 1.80          | 17.70       | 39.67        |
|                        | P₂      | 0.69                  | 3.64                 | 4.33             | 15.77        | 0.49           | 1.80          | 17.70       | 39.67        |
|                        | P₃      | 0.69                  | 3.64                 | 4.33             | 15.77        | 0.49           | 1.80          | 17.70       | 39.67        |
| 5                      | P₁      | 0.95                  | 3.83                 | 4.78             | 19.69        | 0.53           | 2.11          | 21.04       | 47.36        |
|                        | P₂      | 1.07                  | 4.09                 | 5.16             | 20.60        | 0.56           | 2.25          | 23.15       | 52.09        |
|                        | P₃      | 1.13                  | 4.65                 | 5.78             | 19.40        | 0.55           | 2.38          | 26.32       | 59.23        |
| 10                     | P₁      | 0.81                  | 3.83                 | 4.64             | 17.51        | 0.75           | 1.88          | 17.97       | 40.43        |
|                        | P₂      | 0.92                  | 4.02                 | 4.94             | 18.64        | 0.64           | 2.04          | 19.48       | 43.82        |
|                        | P₃      | 0.97                  | 4.23                 | 5.20             | 18.63        | 0.74           | 2.15          | 20.69       | 46.58        |
| 20                     | P₁      | 0.87                  | 3.84                 | 4.71             | 18.36        | 0.57           | 2.01          | 20.45       | 46.01        |
|                        | P₂      | 0.95                  | 4.06                 | 5.01             | 18.79        | 0.59           | 2.12          | 22.88       | 51.52        |
|                        | P₃      | 1.05                  | 4.38                 | 5.43             | 19.17        | 0.60           | 2.19          | 23.90       | 53.79        |
| LSD 0.05               | 0.03    | 0.23                  | 0.09                 | 0.55             | 0.07         | 0.04           | 0.91          | 2.03        |

P₁: one week  P₂: g two weeks  P₃: one month

The data presented in Table (4) also reveal that combination of different rates of potassium silicate and pattern of application has promoting effect on protein and carbohydrate content of cowpea grains. It is clearly noticed that the highest record of protein and carbohydrate content (26.32 and 59.23%) respectively gained by supplying with potassium silicate at rate of 5 L/fed combined with month of pattern. Such effect may be attributed to the beneficial effect of silicon have been associated with increases in photosynthesis (Pilon et al., 2013).

Conclusion

On the basis of above results, it can be concluded that potassium silicate can be recognized as an important plant nutrient and must be included in cowpea fertilization. Cowpea production and quality also affected by pattern of use of potassium application. The dual application of potassium silicate and pattern of use had great effect on yield and yield components as well as macronutrient uptake of cowpea grains. Such effect was more pronounced with rate of 5 L/fed with month of pattern to provide high productivity and quality of cowpea.

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Availability of data and materials

The datasets supporting the results are included within the article.

Authors’ contributions

All authors have contributed significantly to the conception and design of the study, the interpretation of data, and the drafting and revision of the manuscript. All authors read and approved the final manuscript.

Ethics approval and consent to participate

The authors declare that the work is ethically approved and consent to participate.

Consent for publication

The authors declare that the work has consent for publication.
Competing interests

The authors declare that they have no competing interests.

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