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EFFECTS OF MINERAL FERTILIZATION, BIOCHAR AND FULVIC ACID ON SANDY SOIL PROPERTIES AND NUTRIENTS UPTAKE BY WHEAT PLANTS

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ABSTRACT: Nowadays, due to population growth in Egypt, the reclamation of degraded soils e.g., sandy soil is becoming a major strategy for the government. Therefore, the aim of this research work was to improve sandy soil properties and optimize the nutrients uptake of wheat plants, which is one of the most important strategical crops in Egypt using mineral fertilizers and some amendments. Different rates of mineral fertilizers as main plots [NPK_1: 0.47: 0.63: 0.56, NPK_2: 0.71, 1.22: 0.75, NPK_3: 0.94: 1.89: 0.94 and NPK_4: 1.18, 2.52: 1.12, g pot^{-1}], soil addition of biochar as sub plot [B_0:0.0 (without biochar), B_1: 56 and B_2: 113, g pot^{-1}] and foliar application of fulvic acid as sub sub plots [F_0:0.0(without foliar application) and F_1: 0.2, g L^{-1}] were investigated under pot experiment during 2017/2018 season using wheat plants. The obtained results showed that the maximum values of soil available N and P were recorded with applying the maximum NPK fertilizers level combined with biochar at rate of 113, g pot^{-1} and fulvic acid. On the other hand, maximum values of soil available K were reported with applying the maximum NPK fertilizers level without any amendments or without fulvic acid with 113, g pot^{-1} of biochar. Also, the highest values of NPK-uptake in both straw and grains were achieved with applying the maximum NPK fertilizers level combined with biochar at rate of 113, g pot^{-1} and fulvic acid. Generally, it can be concluded that the performance of wheat grown on sandy soil could be optimized by combining NPK fertilizers with biochar amendment, which could reduce nutrient losses, and foliar application fulvic acid, which improved plant resistance against stress conditions of sandy soil under semi-arid conditions.

Key words: Biochar, fulvic acid, sandy soil and wheat plants.

INTRODUCTION

With the massive population increment in Egypt, a great demand for wheat (*Triticum* sp.) as a strategic crop has been detected in parallel with limited soil resources. Increasing wheat crop production is an Egyptian national target to fill the gap between its production and consumption. Therefore, great attention and efforts have been paid by the scientists who work in the agricultural field to reduce the wheat security gap **(Asseng *et al.*, 2018; El-Ghamry *et al.*, 2021).**

In Egypt, the sandy soils represent more than 90% of the total area. So, the reclamation of degraded soils *e.g.,* sandy soil is becoming a major strategy for the government. Sandy soil possesses poor physical and chemical properties as well as its low capacity to retain irrigation water and supplying power for nutrient elements **(Sadek *et al.*, 2011)**.

One of the plants protective ways against low sandy soil fertility is the utilization of soil amendments *e.g.,* biochar or other stimulants *e.g.,* fulvic acid.

Biochar is produced via either thermal decomposition of plant wastes or burning plant residues by exposure to pressure without oxygen under high temperatures **(Lehmann and Joseph, 2009).** From regarding agricultural point of view, the biochar addition leads to retention of

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nutrients and irrigation water for a longer period in the soil due to its high porosity and cation exchange capacity **(Chen *et al.*, 2007).** It also improves the chemical and physical characteristics of the degraded soils *e.g.*, sandy soil **(Rizwan *et al.*, 2016).** It also possesses a high ability to exchange cations, which help to keep nutrient elements in the soil and prevent deposition and loss from the soil **(Atkinson *et al.*, 2010; Sohi *et al.*, 2009).**

Fulvic acid is one of organic acids that has a low molecular weight as well as it is rich in oxygen fulvic acid as a humic substance could enhance the nutrients uptake by higher plants **(Taha *et al.*, 2016).** The size of fulvic acids is smaller than humic, therefore due to the relatively small size of fulvic acid molecules, they can readily enter plant roots, stems, and leaves **(Weng *et al.*, 2006 and Reshi and Tyub, 2007).**

Therefore, the current study aims at assessing the effect of biochar as soil addition and foliar application of fulvic acid in combined with different rates of N, P, and K as mineral fertilizers on the sandy soil properties and performance of wheat plants and find out the superior treatment.

MATERIALS AND METHODS

Experimental Site

A pot trail was implemented during 2017/ 2018 season in the Farm of Faculty of Agriculture Zagazig University, Egypt. Soil samples were collected from Alkhatarh, Sharkia Governorate, Egypt; Northeast of the city of Zagazig and West Ismailia governorate on the road (Qassasin-Port Said) to represent the sandy soil. Soil samples were primary analyzed depending on **Sparks *et al.*, (2020) and Dane and Topp (2020),** where their properties are shown in Table1.

Experimental Setup

The current study aimed at investigating the impact of different mineral fertilization combine with biochar as soil addition and fulvic acid as foliar application on sandy soil properties and nutrients uptake of wheat plants grown under sandy soil condition. Different rates of mineral fertilizers as main plots [NPK_1: 0.47: 0.63: 0.56, NPK_2: 0.71, 1.22: 0.75, NPK_3: 0.94: 1.89: 0.94 and NPK_4:1.18, 2.52: 1.12, g pot^{-1}], soil addition of biochar as sub plot [B_0:0.0 (without biochar), B_1:56 and B_2: 113, g pot^{-1}] and foliar application of fulvic acid as sub sub plots [F_0:0.0(without foliar application) and F_1: 0.2, g L^{-1}] were investigated. The trail was immplemented in a split-split-plot design with three replicates.

Plastic pots (20 cm diameter and 25 cm depth) were filled by air-dry sandy soil equaled to 10 kg oven dry sandy soil. Wheat grains (*Triticum aestivum* CV., Misr 1) were obtained from the Ministry of Agri. and soil Rec (MASR), where fifty grains were sown in each pot in November 25th, then thinning process to 20, 10 and 5 homogenous plants pot^{-1} was done at the tillering, booting and maturity stages, respectively.

All pots received N, P, K mineral fertilizers as ammonium nitrate (335 g N kg^{-1}), superphosphate (60 g P kg^{-1}) and potassium sulfate (396.7 g K kg^{-1}), respectively at above studied rates. Two days before sowing, biochar was added to soil in a single application. Fulvic acid was purchased from El-Gamhoria Company, Egypt, where it was foliar applied after 30 and 60 days from sowing. Harvest process was done on March 25th.

Measurements Traits

After wheat harvesting, soil samples were taken to determine some soil measurments. Soil available N and K were determined depending on **Reeuwijk (2002)**, while soil available P form was determined as described by **Olsen and Sommers (1982**). Soil pH was determined using a Gallen Kamp pH-meter in soil suspension (1:2.5). Soil electrical conductivity (EC) was determined using EC meter Model TDScan 3) in soil water extract (1:5). Total nitrogen content in grains was determined using the micro-Kjeldahl method according to **Jackson (1973)**. Total phosphorus content in grains was determined calorimetrically using the ascorbic acid methods **(Watanabe and Olsen, 1965)**. Total potassium content in grains was determined by a flame photometer according to **Jackson (1973)**. Also, nutrient uptake “NPK” by wheat plants were conducted.

Table 1. Characteristics of the studied sandy soil

Properties	Values
Particle size distribution (%)	
Clay	11.02
Silt	9.59
Sand	78.39
Texture class	Loamy sand
Soil moisture characteristics (%)	
Air dried soil moisture	1.91
Saturation percent	43.5
Total porosity	37.5
Volume expansion	6.71
Bulk density (Mg m^{-3})	1.68
Real density (Mg m^{-3})	2.69
Organic matter (g kg^{-1})	4.95
$CaCO_3$ (g kg^{-1})	4.80
EC (dSm^{-1}) [Soil water extract 1:5]	0.35
pH [Soil suspension 1:2.5]	8.01
Total nutrients (g kg^{-1})	
N	0.38
P	0.02
K	1.11
Available nutrients (mg kg^{-1})	
N	26.6
P	3.12
K	107
Ca	208
Mg	27.3

Statistical Analysis

Data were tested for analysis of variance (ANOVA) based on **Gomez and Gomez (1984)** using **MSTAT-C. (1991)**. Treatment means were compared using least significant differences (LSD) test at 0.05 level of probability (**Waller and Duncan, 1969**).

RESULTS

Effects of NPK Rates, Biochar and Fulvic Acid on Soil Chemical Properties and Nutrients Availability

Fig. 1 A shows the impacts of all possible combination treatments among mineral fertilizers rates and biochar amendment and foliar application of fulvic acid on available soil N content. The highest value of available soil N was 63.59 mg kg^{-1}, where it was recorded under the addition of maximum NPK fertilizer and biochar combined with foliar application of fulvic acid. While the lowest value of available soil N was 31.09 mg kg^{-1} under the lowest NPK fertilizer level without biochar or fulvic acid. It is worth mentioning that biochar application at a rate of 113 g pot^{-1} combined with spraying fulvic acid within the same level of mineral fertilizers possessed higher influence on raising soil N content than soil addition of biochar at rate of 56 g pot^{-1} with fulvic acid followed by biochar at rate of 113 g pot^{-1} without fulvic acid. Soil N content under NPK_3 and NPK_4 treatments without biochar amendment or foliar application of fulvic acheived the similar values under combining NPK_2 with 113 g pot^{-1} of biochar amendment and fulvic acid.

Similarly, the maximum value of available soil phosphorus was 38.35 mg kg^{-1} when under the maximum NPK fertilizers level combined the highest rate of biochar (113 g pot^{-1}) and foliar application of fulvic acid. While the minimum

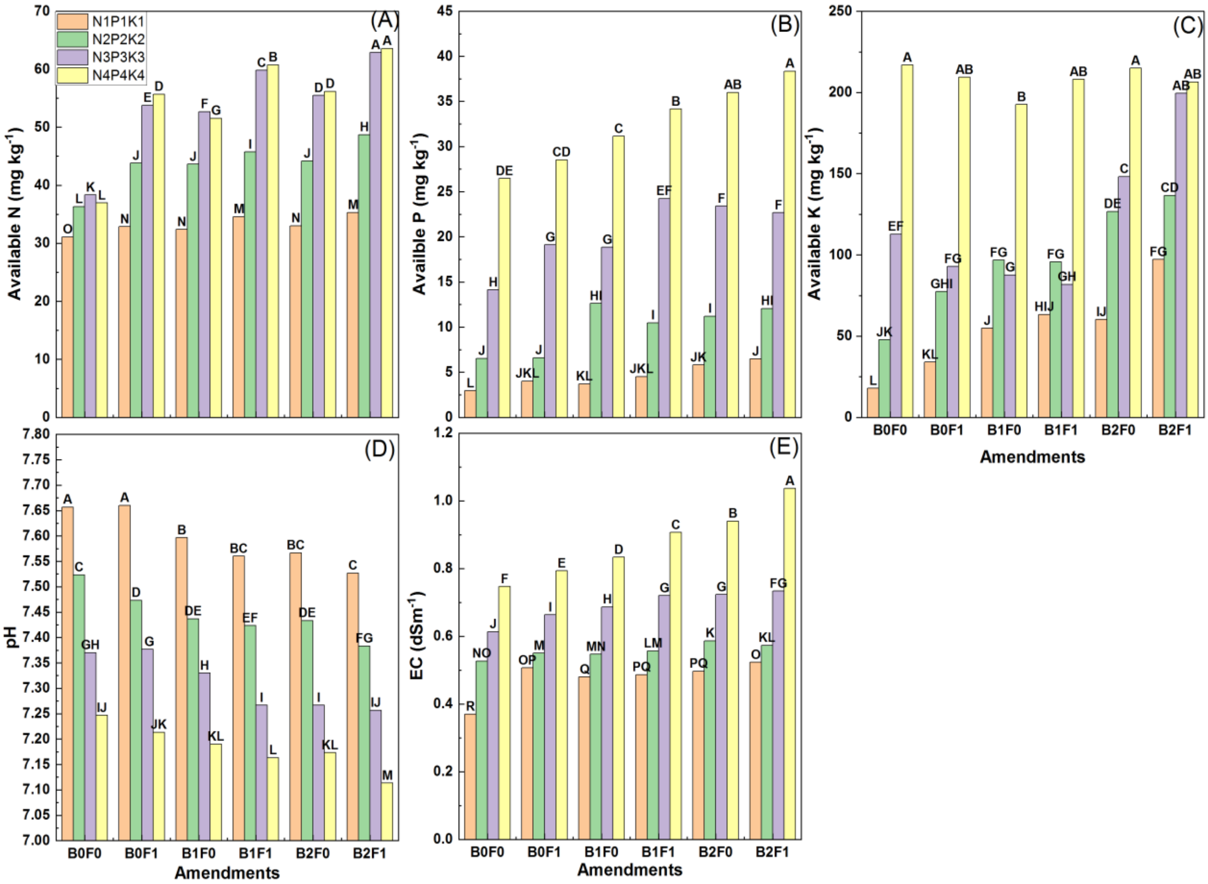

Fig.1. Effect of NPK rates combined with biochar and fulvic acid on soil chemical properties

N1, N2, N3 and N4 refer to the ammonium sulphate rates (0.47, 0.71, 0.94 and 1.18 g pot^{-1}). P1, P2, P3 and P4 refer to super phosphate at rates (0.63, 1.22, 1.89 and 2.52 g pot^{-1}). K1, K2, K3 and K4 are potassium sulphate rates (0.56, 0.75, 0.94 and 1.12 g pot^{-1}). B0, B1 and B2 are biochar rates (0, 56 and 113 g pot^{-1}). F0 and F1 are the fulvic acid rates (0 and 0.2 g L^{-1}). Letters above columns refer to the significant level at p<0.05.

value of available soil phosphorus was 2.96 mg kg^{-1}, under the lowest NPK level without biochar amendment or fulvic acid (Fig.1B). Differently, combining mineral NPK fertilizers with 113 g pot^{-1} of biochar and fulvic acid realized the highest impact on available soil phosphorus followed by no fulvic acid application, then biochar at rate of 56 g pot^{-1} with fulvic acid. Also available soil P was influenced mainly by fertilizers levels with less impact of other amendments, where NPK_4 without biochar or fulvic acid recorded the maximum available soil P than other levels even combined with biochar amendment and fulvic acid.

On the contrary, the highest values of available soil K (216.79 and 214.88 mg kg^{-1}) were achieved with applying the highest NPK fertilizers level without any studied amendments or with biochar at rate of 113 g pot^{-1} without foliar application of fulvic acid (Fig. 1C). It is worth mentioning that available soil potasium under all combinations with NPK_3 and NPK_4 with biochar (113 g pot^{-1}) and fulvic acid possessed no notable differences (around 25 mg kg^{-1}), while these differences were increased to more than 40 mg kg^{-1} under NPK_3 combined with biochar amendment at rate of 113 g pot^{-1} without fulvic acid.

Regarding soil EC, the maximum EC value was 1.04 dS m^{-1} due to applying the maximum mineral fertilizers level (NPK_4) combined with biochar amendment at rate of 113 g pot^{-1} and fulvic acid, while the lowest EC value was 0.37 dS m^{-1} due to applying the lowest fertilization level without soil addition of biochar or foliar application of fulvic acid as shown in Figure 1 (E). EC value took the following descending order within the same mineral fertilizer rate; Biochar at rate of 113 g pot^{-1} + fulvic acid > Biochar at rate of 113 g pot^{-1} without fulvic acid > Biochar at rate of 56 g pot^{-1} +fulvic acid > Biochar at rate of 56 g pot^{-1} without fulvic acid > single foliar application of fulvic acid.

Concerning pH value, the maximum soil pH was 7.66, where it was recorded with the lowest fertilization level without any studied amendments or combined with foliar application of fulvic acid only, while the lowest value of soil pH (7.11) was realized under applying the highest mineral fertilizers level (NPK4) with biochar at rate of 113 g pot^{-1} and foliar application of fulvic acid (Fig. 1 D). Under the same NPK fertilization level, the impact of the studied amendments on reducing soil pH took similar descending order just like their influence on increasing EC value, but there were no notable differences among soil pH treated with biochar (113 g pot^{-1}) without fulvic acid and that treated with biochar (56 g pot^{-1}) with fulvic acid or biochar (56 g pot^{-1}) without fulvic acid and single foliar application of fulvic acid.

Response of Nutrients Content in Wheat Straw and Grains to the Fertilizers Rates, Biochar and Fulvic Acids

Figs. 2 and 3 shows the effect of the studied treatments on grains nutrient content *i.e.*, N, P, K (GNU, GPU, GKU) and straw nutrient content *i.e.*, N, P, K (SNU, SPU and SKU).

Maximum values of all aforementioned traits were 2.37, 0.59, 2.36, 2.88, 0.97 and 2.31% for SNU, SPU, SKU, GNU, GPU and GKU, respectively, obtained by the addition of maximum NPK fertilizer and biochar rate and fulvic acid. While the lowest values (0.91, 0.16, 1.20, 1.49, 0.2 and 1.04 %) for SNU, SPU, SKU, GNU, GPU and GKU, respectively were realized with the lowest NPK fertilizer level without both biochar and fulvic acid for all traits except GNU which possessed the lowest value with applying the lowest NPK fertilization rate with fulvic acid. Generally, it can be noticed that SNU, SPU, SKU, GNU, GPU and GKU values showed various responses to the addition of biochar amendment and foliar application of fulvic acid combinations within the same fertilization rate.

There were non significant differences in the response of SNU (between 2.1-2.18 %) to the addition of maximum NPK fertilizers rate mixed with biochar (113 g pot^{-1}) without fulvic acid, mixed with biochar (56 g pot^{-1}) and fulvic acid or NPK3 with biochar at rate of 113 g pot^{-1} and foliar application of fulvic acid (Fig. 3A). Applying treatment of NPK3 with any level of biochar conditioner with or without fulvic acid as foliar application recorded SNU value higher than NPK3 combined with foliar application of fulvic acid only.

SPU values responded differently to the decreases of fertilization level combined with other studied amendments, where the lowest SPU value (0.36%) under NPK 4 was realized under the combined addition with biochar at rate of 56 g pot^{-1} and fulvic acid, but not at NPK 4 with fulvic only like SNU values (Fig. 3 B). Within the same fertilization level, SKU values reduced notably under single addition of biochar at rate of 56 g pot^{-1}, but still higher than that of plants grown without the studied amendments (Fig. 3 C). Combined additions of biochar at rates of 56 and 113 g pot^{-1} with or without foliar application of fulvic acid resulted in conserving SNU, SPU, SKU, GNU, GPU and GKU values higher than that with plants grown without the studied amendments even with dropping the fertilization level down to the lower level.

DISCUSSION

The wheat plants grown on sandy soil are possessing low productivity due to its low content of organic matter and available macro and micronutrients. Biochar application has a positive role in improving the growth of wheat plants in sandy soil owing to its great specific surface, therefore it can retain more irrigation water and nutrients in the root zone to be uptaken by wheat plants as needed. Additionally, biochar improves most of soil properties as mentioned by **Ghazi and El-Sherpiny (2021)**. On the other hand, the superiority of foliar application of fulvic acid and its positive role in enhancing the nutrients uptake may be attributed to the small particles that can enter plant roots, stems, and leaves **(Weng *et al.*, 2006; Reshi and Tyub, 2007)**.

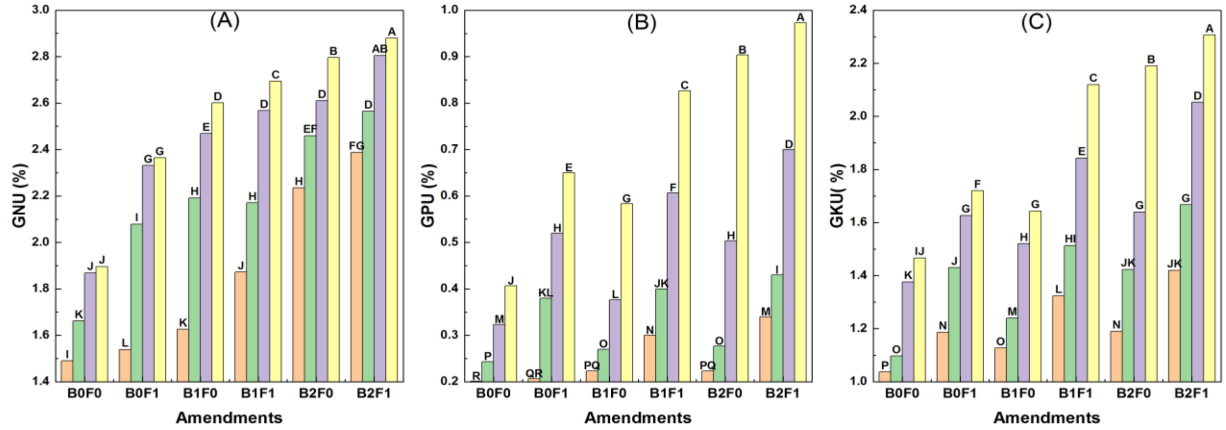

Fig. 2. Effect of NPK rates combined with biochar and fulvic acid on grains content of N, P and K (see footnote in Fig. 1).

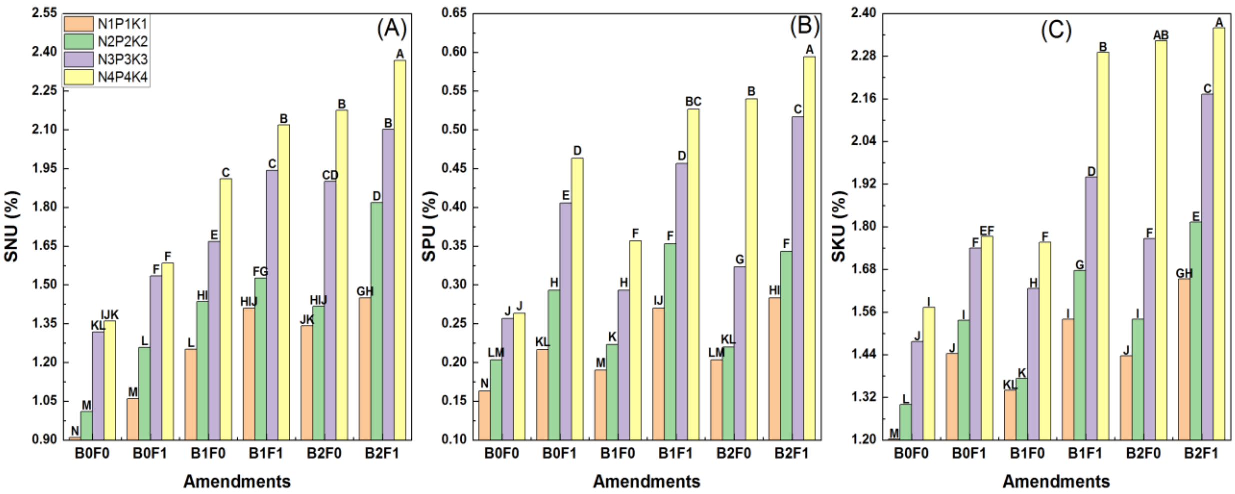

Fig. 3. Effect of NPK rates combined with biochar and fulvic acid on straw content of N, P and K (see footnote in Fig. 1)

Effects on Soil Chmical Properties

Poor soil fertility attributes to its low contents of colloids particles and CEC, so it has very small ability to store available nutrients for plant. Therefore, there were increments in soil contents of macronutrients with raising the application rate of NPK fertilizers to level 3 that possess the same impact of level 4. That refers to the losses of N, P and K elements and removal from sandy soil via leaching or volatilization **(Kandil *et al.*, 2016)**. The increments in soil mineral contents *e.g.*, N, P and K were accompanied by increments in soil EC and reductions in soil pH (**Šimanský *et al.* 2019**). The decrease of soil pH value by NPK fertilizers may be due to leaching of basic cations, like calcium, potassium, and magnesium from the soil. Additionally, NPK fertilizer treatment acidified the soil as the ammonium nitrate that was used in this study was uptake by wheat plants as NH_4^+ first and then the H^+ was released into soil, which thereby decreased the soil pH. The long-term utilization of NPK fertilizer eventually results in deficiencies in other essential nutrients, which may deteriorate the physical, chemical, and biological properties of the soil (**Haileselassie *et al.*, 2014**).

From the obtained results, biochar addition with high specific surface and CEC led to increase the ability of sandy soils to catch more elements even under high fertilization levels of mineral NPK fertilizers with less influences of fulvic acid. Also, biochar can overtake the role of sorption complex and exchange cations with soil solution **(Ghazi and El-Sherpiny, 2021)**. Biochar helps to create soil aggregate structure and mesopores in soil, which are conducive to keep water and nutrients available for plants (**Van Zwieten *et al.* 2010)**.

Effects on Nutrients Conten in Grains and Straw

Applying 100% of recommended doses of N, P and K recorded the highest N, P and K contents in grains and straw. Obtained findings are in harmony with those reported by **Dolijanović *et al.* (2019)**, who indicated that the application of mineral nitrogen fertilizer increased the N element content in grains**.** Besides, **Svecnjak *et al.* (2013**) noticed that the mineral fertilizer increased the N content uptake by wheat plant over control treatments. **Kiani *et al.* (2005)** indicated that N content in grains and straw of wheat was significantly improved by integrated application of N, P and K (**Peoples *et al.* 2017**).

The superior of bichar may be attributed to the fact that biochar conditioner can avoid nutrient losses by leaching may favor an increase in the availability of nutrients in soil in the long term. Interestingly, biochar amendment possess a positive effects on plant nutrition, being this result corroborated by the increase detected in the resin-extractable phosphate concentration after biochar amending **(Atkinson *et al.*, 2010**).

These increments were optimized by applying biochar conditioner, which reduced the losses of nutrients and improved soil properties. The beneficial effects of biochar are determined primarily by some of its properties: high porosity, responsible for its high water retention capacity; high cation exchange capacity, which favors the retention of nutrients and prevent their loss (**Ghazi and El-Sherpiny, 2021).**

Conclusion

It can be concluded that the performance of wheat grown on sandy soil could be optimized by combining NPK fertilizers with biochar, which could reduce nutrient losses, and foliar application fulvic acid, which improved plant resistance against poor sandy soil. On the other hand, the soil addition of biochar improved the properties of sandy soil.

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تاثير التسميد المعدني والفحم الحيوي(البيوشار) وحمض الفولفيك على خصائص التربة الرملية وامتصاص العناصر الغذائية بواسطة نبات القمح وصلاحية العناصر الغذائية

نوران حسام شلتوت - أحمد حسين ابراهيم - محمد كمال عبد الفتاح – أحمد إبراهيم السيد عبده

قسم علوم الأراضي - كلية الزراعة - جامعة الزقازيق - مصر

في الوقت الحاضر، بسبب النمو السكاني في مصر، أصبح استصلاح الاراضي المتدهورة، مثل التربة الرملية، استراتيجية رئيسية للحكومة. لذلك، كان الهدف من هذا البحث هو تحسين خصائص الاراضي الرملية وتحسين امتصاص نبات القمح الذي يعتبر أحد أهم المحاصيل الاستراتيجية في مصر للعناصر الغذائيه باستخدام الأسمدة المعدنية وبعض الإضافات تحت ظروف التربة الرملية. تم دراسة معدلات مختلفة للأسمدة المعدنية [NPK_1 بالمعدلات 0.47: 0.63 : 0.56 و NPK_2 بالمعدلات 0.71 : 1.22 : 0.75 و NPK_3 بالعدلات 0.94 : 1.89 : 0.94 و NPK_4 بالمعدلات 1.18 : 2.52 : 1.12 جرام لكل أصيص]، إضافات أرضية للبيوشار [B_0 : (بدون الفحم الحيوي)، B_1: 15 و B_2 :30 ، طن/الهكتار] والرش الورقي لحمض الفولفيك [F_0: (بدون رش ورقي) وF_1:0.2، جم/لتر] في تجربة أصص خلال موسم 2018/2017 باستخدام نباتات القمح. أظهرت النتائج المتحصل عليها أن القيم القصوى لمحتوي التربة من النيتروجين والفسفور تم تسجيلها مع تطبيق الحد الأقصى لمستوى الأسمدة المعدنية NPK_4 مع الفحم الحيوي بمعدل 113 جرام/ أصيص والرش الورقي لحمض الفولفيك بينما كانت القيم القصوى لمحتوي التربة من البوتاسيوم مع تطبيق الحد الأقصى لمستوى الأسمدة المعدنية NPK_4 بدون أي إضافات ارضيه وورقية أو بدون حمض الفولفيك مع الفحم الحيوي بمعدل 30 طن/الهكتار. أيضا، تم تحقيق أعلى قيم امتصاص NPK في كل من القش والحبوب مع تطبيق الحد الأقصى لمستوى الأسمدة المعدنية NPK_4 مع الفحم الحيوي بمعدل 113 جرام/ أصيص والرش الورقي لحمض الفولفيك. بشكل عام، يمكن استنتاج أن أداء القمح المزروع في التربة الرملية يمكن تحسينه من خلال الجمع بين الأسمدة المعدنية مع الفحم الحيوي كمحسن للتربة، مما قد يقلل من فقد المغذيات، والرش الورقي لحمض الفولفيك، مما يحسن مقاومة النبات ضعف خصوبة التربة الرملية.

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