Interaction Effect of Different Concentrations of Nano-Fertilizer (NPK) and Sources of Charcoal on Growth and Yield Parameters of Faba bean (Vicia faba L.)

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Abstract. The application of charcoal to agricultural soils is mostly used to improve soil fertility and crop products around the world, but as a scientific researching could be quite neoteric in our region, Kurdistan. Alongside of different sources of charcoal as first factor, nanotechnology was also used as second factor in this research to improve growth and yield parameters of Vicia faba L. The results revealed to the single effect of each of charcoal and Nano-NPK fertilizers and its interaction on studied parameters. Plant height in the control treatment recorded 63.00cm which was dramatically increased to (72.56, 72.64, 75.48cm), respectively in the soil treated with (Local, China and Straw Charcoals), respectively. Additionally, number of pods per plant, pod length and fresh yield per plant were (30.92, 17.59cm, 141.84g) for control treatment, which were increased significantly to (37.81, 18.71cm, 246.34g), for treatments straw charcoal or ash added to the soil, Nano-NPK fertilizers at concentrations of 100 and 200 mg L⁻¹ respectively. Significantly affected on growth and yield parameters. The number of pods, pod length and fresh yield were (23.75, 16.35cm, 83.13g), respectively in the control treatment (C₀N₀), while in the interaction treatment between charcoal Cᵧ(Straw Charcoals) and Nano NPK N₂ (200 mg L⁻¹) caused significant increase in their values to (47.75, 19.07cm, 261.67g).

1. Introduction

(Vicia faba L.) is one of the important winter vegetable crops belongs to Fabaceae family. The amount of protein and carbohydrates of its seed too high which is about (25-30% and 56%), respectively [1,2]. Divya and Jisha [3] reported that faba bean traditionally used to nitrogen fixation and as a cover crop to prevent erosion of the soil, and is appreciated for its good agronomic characteristics. Improve quality and quantity of faba bean are more important, so for that purpose many ways have been done. Adding fertilizers are one of the ways to provide high amount of product and in the same time to have the best quality.

Nanotechnology proved its importance in agriculture nowadays. Research is being developed to provide nutrients to crop plants using nanofertilizers. Nano fertilization could be done by three methods: seed priming, foliar application or soil incorporation [4]. Foliar application of nanofertilizers showed different results with several crops with respect to enhancement of growth and increased productivity.

Nanotechnology has been proved to be used in various fields. It can be used in increasing crop production and protection. Its applications have been spread globally in small concentrations. Also, it may be less expensive than traditional methods [5]. Moreover, nanoparticles were applied to improve some growth and yield parameters of broad bean by [6]. Nano-Boron was adding to faba bean which was caused to increase nitrogen, phosphorus, boron and chlorophyll in the leaves and the dry matter content of plants [7,8] concluded that foliar application of Zn, Fe and NPK, through the action as a growth promoter, can increase in the plant growth and seed yield in chickpea.

Beside of nano-fertilizer different sources of charcoal were used during this current study which was also to know its influence on growth and yield parameters of faba bean growth and yield parameters were significantly affected by charcoal and charcoal with potassium and also using different sources and sizes of charcoal were suggested to improve quality and quantity of crops [9,10] reported that the high grain yield of faba bean was significantly obtained from integrated application of 46 kg P₂O₅ ha⁻¹ with the agricultural lime, coffee husk ash and coffee husk charcoal with the observed values of 2265, 1953 and 1943 kg ha⁻¹, respectively. Activated charcoal (10 g L⁻¹) with other medium were greatly reduced lethal browning in explants and improved shoot regeneration of faba bean [11]. Additionally, all the physiological and biochemical attributes in maize seedlings under drought conditions were improved by adding biochar at the rate 4 t ha⁻¹ [9,12,13] believed that
Investigation of several biochars in different crop species is important to understand their influence on growth and yield parameters.

Since there are little or no studies about Nano - NPK fertilizer and charcoal, for this reason this research aimed to study: The role of concentrations of Nano- NPK and sources of charcoals and their interactions on growth and yield of faba bean.

2. Materials and Methods

2.1. Materials

Seeds of faba bean (Franchi Sementi, dal 1783), used as plant material for this study. Different levels of nano-NPK (Khazra Nano Chelated NPK 20-20-20 Fertilizer, Fertilizer Reg. No: 61188) and charcoals were used as second factors. Sources of charcoal includes; China was represented as C_1, C_2 represent Local and C_3 represent straw charcoal or ash. Figure 1 shows the types of charcoal and straw were used in the current study.

Figure 1. Types of charcoals used in field experiment.

Image (a) is the charcoal which was China types normally has in the markets; (b) local types was also collected from the market; (c) straw collected from Gerdarasha Agriculture Research Station, it was burnt then used as a source of carbon; (d) sieved charcoal or its powder (Figure 1). Additionally, (Thiocyclam Hydrogen Oxalate 50%, Krishi Rasayan Exports Pvt. Ltd. - India) as pesticide was used to control insects.

2.2. Location of Experiment

The experiment was conducted at Gerdarasha Agriculture Research Station, College of Agricultural Engineering Sciences, Salahaddin University-Erbil, Kurdistan region, Iraq (Figure 2).

Figure 2. Map of Gerdarasha Agriculture Research Station, Department of Field Crops, College of Agricultural Engineering Sciences, Salahaddin University-Erbil.
The mean annual air temperature is estimated at about 20 °C with a minimum in January (5 °C) and a maximum of 25 °C during faba growth, amount of rainfall was between December and May (Figure 3).

![Figure 3. Metrological data recorded at the experimental site.](image)

2.3. Field Experiment

The field experiment was laid out in a Factorial Randomized Complete Block Design (RCBD) with three replicates. Three different concentrations of Nano-NPK were presented as N were applied (N_0 = control, N_1 = 100 and N_2 = 200 mg L^{-1}), while C represent as charcoal so (C_0 = Control, C_1 = China, C_2 = Local and C_3 = Straw charcoal or ash) 1 kg was applied for each experimental unit as a powder which was equal to 6666.7 kg/ha. Seeds were planted on 5th December, 2019 at a soil depth of 3-5 cm in a plot with size of 1m²×1.5m². The distance between plants was 30 cm and 25 cm were between rows which was totally four rows in each plot.

Charcoals were mixed with the soil before planting, while foliar application of Nano-NPK was done on 10th March 2020. The first picking was done at the middle of April 2020, and the second picking on 29 April 2020. Table 1 shows some properties of the soil at the experimental site.

Table 1. Some physical and chemical properties of the field soil.

| Physical Properties          | Value | Unit   |
|------------------------------|-------|--------|
| Particle Size Distribution   |       |        |
| Sand                         | 243   | g.Kg^{-1} |
| Silt                         | 421   | g.Kg^{-1} |
| Clay                         | 336   | g.Kg^{-1} |
| Clay Loam                    |       |        |
| Texture Class                |       |        |
| Bulk Density                 | 1.42  | g.cm^{-3} |
| Infiltration Rate            | 37.42 | cm.hr^{-1} |
| Chemical Properties          |       |        |
| PH                           | 7.42  |        |
| ECe                          | 0.47  | dS m^{-1} |
| Organic Matter               | 9.60  | g.Kg^{-1} |
| Carbonate Mineral CaCO_3     | 306   | g.Kg^{-1} |
| Active CaCO_3                | 15.80 | g.Kg^{-1} |
| Total Nitrogen               | 0.25  | g.Kg^{-1} |
| Available Phosphorus         | 3.50  | mg.Kg^{-1} |
| Potassium                    | 0.78  | Mmol L^{-1} |
| CEC                          | 23.90 | Cmole Kg^{-1} |
| Calcium                      | 3.00  | Meq L^{-1} |
| Magnesium                    | 1.50  | Meq L^{-1} |
| SO_4^{2-}                    | 1.30  | Meq L^{-1} |

Source: [14].
2.4. Data Analysis

Statistical analysis was done using SPSS program version 25 for comparing between means using Duncan’s multiple range test at probability (p ≤ 0.95), (Cochran and Cox 1957). The principal component analysis (PCA) was performed for comparing between the studied treatment combinations using XLSTAT-Premium Program [15].

3. Results and Discussion

Different concentrations of Nano-fertilizers with sources of carbon were used in this study, so results showed significant effect of both factors on studied traits. Generally, the best values of all growth and yield parameters were recorded when straw charcoal added to the soil which was recorded the highest plant height, leaf area index, number of pods per plant, number of seeds per pod and pod length were (75.48cm, 24.64cm², 37.81, 5.90 and 18.71cm), respectively (Table 2). It was also true for the fresh yield and dry matter plant⁻¹. As [16] reported that biochar positively influenced growth and yield of French bean. In previous work [17], charcoal was added to Tomato field, so fruit yield increased with application of charcoal compared to without charcoal. Similarly, [18] showed that biochar’s provided greater benefits to faba bean yield by addressing P nutrition and improving al toxicity. Some parameters also significantly affected by local and China charcoals but as stated the best results were recorded with the straw charcoal. This may be related to the chemical components and its rate of the straw compared to the local and China charcoals. Additionally, reaction of the straw charcoal may so fast to the soil compared to the other charcoal types which depends on hardness of the charcoal especially china charcoal was too hard since it was compacted in the factory.

Table 2. Effect of different carbon sources on some growth and yield characteristics of faba bean.

| Treatment | Plant height (cm) | No of brunch | LA (cm²) | No of pod plant⁻¹ | Pod length (cm) | No seed pod⁻¹ | Fresh yield plant⁻¹ (g) | Dry matter plant⁻¹ (g) |
|-----------|------------------|--------------|----------|-------------------|----------------|----------------|-------------------------|------------------------|
| Control   | 63.00ᵃ           | 3.56ᵃ        | 17.35ᵃ   | 30.92ᵇ           | 17.59ᵇ         | 4.51ᵇ         | 141.84ᵇ                 | 50.36ᵇ                 |
| Local Charcoal | 72.56ᵇ           | 4.60ᵃ        | 20.75ᵇ   | 35.75ᵇ           | 18.15ᵇ         | 4.97ᵇ         | 188.89ᵇ                 | 58.15ᵇ                 |
| China Charcoal | 72.64ᵇ           | 4.53ᵃ        | 20.81ᵇ   | 35.57ᵇ           | 18.07ᵇ         | 5.07ᵇ         | 203.67ᵇ                 | 61.00ᵇ                 |
| Straw Charcoal | 75.48ᵃ           | 4.38ᵃᵇ       | 24.64ᵃ   | 37.81ᵃ           | 18.71ᵃ         | 5.90ᵃ         | 246.34ᵃ                 | 63.31ᵃ                 |

Results in table 3 shows the significant effect of Nano-NPK on growth and yield parameters. Plant height increased significantly with adding Nano fertilizer as a rate of 100 mg L⁻¹ NPK to 72.58 cm, in comparing with control treatment just which was 67.92 cm. These results in agreement with [8], who reported that growth and yield parameters of chickpea were significantly increased with applying nano - NPK as compared to plants in control treatment. Generally, N₂ 200 mg L⁻¹ had higher effect compared to N₁ 100 ppm and control treatments, while in some cases did not find any significant differences between N₁ and N₂. It means that both of them necessary to improve growth and yield parameters of faba bean. However, results from this research were in agreement with those reported by [19]. They found that plant parameters and weight of seeds yield (t fed⁻¹) of Soybean was affected by NPK nano-fertilizers shared with mineral NPK at different rates. In another trial also, 10 percent nano - NPK fertilizer which is commercial one, treated as a foliar spray on wheat crop improved the quality of wheat grain [20].

Table 3. Effect of different concentrations of Nano-NPK on some growth and yield characteristics of faba bean.

| Treatment | Plant height | No of brunch | LA (cm²) | No of pod | Pod length | No seed | Fresh yield | Dry matter |
|-----------|--------------|--------------|----------|-----------|------------|---------|-------------|------------|
| Control   | 63.00ᵇ       | 3.56ᵃ        | 17.35ᵃ   | 30.92ᵇ   | 17.59ᵇ    | 4.51ᵇ   | 141.84ᵇ    | 50.36ᵇ     |
Interaction between carbon sources and Nano-NPK fertilizers, were significantly affected on growth and yield parameters. Plant height was dramatically increased with interaction between C and N. The plant height was 51.40 cm in the control, but it was increased to 76.40 cm in the interaction treatment between China charcoal to 200 mg L⁻¹ NPK (C₃N₂) as show from (Table 4). The number of branches was also affected by interaction treatment which was only 3.13 in the control treatment, while increased to (5.20 and 5.00) in the combination treatments of (C₃N₁ and C₃N₁), respectively.

The combination treatments or interaction treatments were affected significantly on leaf area the lowest value (17.21 cm²) was recorded from the control treatment, while the value increased significantly to (18.32, 20.71, 25.11) cm², for treatment combinations of (C₃N₀, C₃N₀ and C₃N₀) (Local without Nano, China without Nano and Straw without Nano), respectively (Table 4). It thought that, the ability to absorb Nano-NPK increased with increasing leaf area while as indicated leaf area improved due to effect of charcoals, then it causes to improve other growth and yield parameters especially can be seen these effects more clearly in the interaction combination C₃N₂ on number of pods, pod length, number of seeds and fresh yield parameters. Results strongly supported by findings of [9] who reported that the interaction between charcoal and potassium at the rate of (800g potassium m⁻² and 60kg ha⁻¹), respectively were caused significantly improve some growth and yield parameter of flax. Additionally, nutrient contained in ash tend to mineralize gradually in the soil to increase nutrient elements for plant absorption, improving soil properties of soil as well as increased yield of crops [21].

Table 4. Interaction effects of different carbon sources and different concentrations of Nano-NPK on some growth and yield characteristics of faba bean.

| Treatment | Plant height (cm) | No of brunch | LA (cm²) | No of pod plant⁻¹ | Pod length (cm) | No seed pod⁻¹ | Fresh yield plant⁻¹ (g) | Dry matter plant⁻¹ (g) |
|-----------|------------------|--------------|----------|-------------------|----------------|----------------|------------------------|------------------------|
| C₀        |                  |              |          |                   |                |               |                        |                        |
| N₀        | 51.40_ab         | 3.13_ab      | 17.21_f  | 23.75_d           | 16.35_b        | 4.04_d        | 83.13_e                | 46.84_f                |
| N₁        | 69.53_ab_bc      | 3.20_ab      | 16.48_f  | 33.00_cd          | 17.55_ab       | 4.60_cd       | 159.27_d               | 48.83_def              |
| N₂        | 68.07_ab_bc      | 4.33_ab      | 18.35_def | 36.00_bc          | 18.87_ab       | 4.91_c        | 183.13_ed              | 55.43_bc_f             |
| N₃        | 70.73_ab_cde     | 4.27_ab      | 20.71_f  | 38.75_bc          | 18.63_ab       | 5.02_bc       | 240.67_ab              | 56.33_bc_c             |
| N₄        | 70.52_ab_bc      | 5.20_a       | 17.54_e  | 32.33_d           | 17.89_ab       | 5.00_bc       | 166.53_d               | 57.67_bcd              |
| N₅        | 76.40_ab         | 4.33_ab      | 23.99_ab | 36.17_bc          | 17.94_ab       | 4.90_c        | 159.47_d               | 60.45_bc               |
| N₆        | 73.20_ab_cde     | 4.33_ab      | 18.32_def | 32.21_d           | 17.59_ab       | 5.17_bc       | 165.00_d               | 46.09_f                |
| N₇        | 75.33_ab         | 5.00_a       | 23.25_ab | 44.25_ab          | 18.38_ab       | 5.33_bc       | 210.33_bc              | 65.25_ab               |
| N₈        | 69.40_bc         | 4.27_ab      | 20.85_bcd | 30.25_d           | 18.24_ab       | 4.73_a        | 235.67_ab              | 71.67_a                |
| N₉        | 76.33_ab         | 4.67_ab      | 25.11_a  | 30.50_d           | 17.98_ab       | 5.28_bc       | 247.67_ab              | 54.99_cd               |
| N₁₀       | 74.93_ab         | 3.87_ab      | 23.73_ab | 35.17_bc          | 19.07_a        | 5.73_b        | 229.80_ab              | 73.67_a                |
| N₁₁       | 75.17_ab         | 4.60_ab      | 25.08_a  | 47.75_a           | 19.07_a        | 6.70_a        | 261.67_a               | 61.28_bc               |
Table 5 shows correlation between growth and yield parameters. Fresh yield was increased significantly with the plant height, leaf area, number of pods, pod length, number of seeds and dry weight with the correlation coefficient values of (0.70, 0.70, 0.60, 0.82, 0.73 and 0.61) respectively. On the other hand, highly significant (P < 0.01) correlations were found between fresh yield, pod length and number of seeds. Additionally, significant (P<0.05) correlations were found between leaf area index, fresh yield and plant height. It believed that, if could improve growth parameters could improve quality and quantity.

Table 5. Correlation between the studied characteristics.

| Parameters | Fresh yield | Plant height | No. of branch | LA | No. of pod | Pod length | No. of seed | Dry weight |
|------------|-------------|--------------|---------------|----|------------|------------|-------------|------------|
| Plant height | 0.70*       |              |               |    |            |            |             |            |
| No. brunch | 0.50        | 0.61*        |               |    |            |            |             |            |
| LA         | 0.70*       | 0.66*        | 0.42          |    |            |            |             |            |
| No. pod    | 0.60*       | 0.62*        | 0.49          | 0.54 |            |            |             |            |
| Pod length | 0.82**      | 0.68*        | 0.47          | 0.68* | 0.74** |            |             |            |
| No seed    | 0.73**      | 0.68*        | 0.48          | 0.69* | 0.78** | 0.74**     |             |            |
| Dry weight | 0.61*       | 0.44         | 0.34          | 0.59* | 0.36   | 0.66*      | 0.42        |            |

*Correlation is significant at level of significance 0.05.
** Correlation is significant at level of significance 0.01.

In Principal Component Analysis (PCA) number of components is equal to variable number, the eigenvalues can be used to determine the number of (PC=F) they can be retained for further study. The scree plot also shows cumulative variation and the slope becomes zero after F6 (Figure 4). The highest variability (64.545%) was due to F1 after F4 variability becomes less than 5% which can be neglected in field experiment (Table 6).

Table 6. Explains eigen values, variability and cumulative variability of different factors.

| F1 | F2 | F3 | F4 | F5 | F6 | F7 | F8 |
|----|----|----|----|----|----|----|----|
| 5.16 | 0.81 | 0.67 | 0.49 | 0.39 | 0.26 | 0.16 | 0.04 |
| 64.55 | 10.14 | 8.39 | 6.18 | 4.88 | 3.30 | 2.00 | 0.55 |
| 64.55 | 74.69 | 83.08 | 89.26 | 94.14 | 97.44 | 99.45 | 100.00 |

The F1= Plant height +No. of branch + LA+ No. of pod + pod length + No. of seed + yield + dry weight, since the factor loadings (correlation coefficient of them is ≥ 0.05 as shown from (Table 7).
Table 7. Correlation Between Variables and Factors.

|                | F1  | F2  | F3  | F4  | F5  | F6  | F7  | F8  |
|----------------|-----|-----|-----|-----|-----|-----|-----|-----|
| Plant height   | 0.86| -0.17| 0.09| -0.22| -0.28| -0.29| 0.03| -0.09|
| No. branches   | 0.65| -0.28| 0.69| -0.01| 0.09 | 0.10 | 0.01| 0.04 |
| Leaf Area      | 0.79| 0.31 | 0.05| 0.42 | -0.29| -0.07| -0.08| 0.08 |
| No. pods       | 0.80| -0.40| -0.19| 0.22 | 0.34 | -0.14| -0.18| -0.03|
| Pod length     | 0.87| -0.10| -0.28| 0.36 | 0.01 | 0.00 | 0.10 | 0.14 |
| No. seeds      | 0.87| -0.17| -0.21| 0.24 | 0.02 | 0.14 | 0.29 | -0.04|

In figure 5 dry weight, LA and yield were located in the second quarter of the cycle, since their correlation with F1 is positive and with F2 is negative the correlation between them and both F1 and F2 have two values while the other parameters were located at the fourth quarter of circle as shown from (Table 6).

Figure 5. PCA Biplot for F1 and F2.

Figure 6 explains the mean of the studied parameters, the interaction treatments or combination treatments which located in 2nd and 4th quarters having higher value while the treatment combination at 1st and 3rd have lower value. Or they classified into 4 groups.
4. Conclusion

It could conclude that, charcoals and Nano-NPK fertilizers have effectually role in improving growth and yield parameters of faba bean. If going back to the results also can receive that fact clearly. Generally, the best results were recorded with the interaction between straw charcoal or ash to 200 mg L\(^{-1}\) of Nano-NPK. Furthermore, highly effect of straw charcoal compared to local and China charcoals in most cases on growth and yield parameters was really interested, since here can say that in the same time reached to two purposes; the first purpose was control the field from the weed and the second was using these weeds (straw) as a source of carbon. Depending on the results of the research project the following points were recommended:

1-Using the Nono-fertilizers and charcoal in farmer fields.
2- It is of evidence that if farmers using charcoals or ash efficiently in their land under scientific recommendations with non-availability of fertilizers may in a lot of cases crop food sustainability can be achieved easily.

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