Research Article

Quality of Reclaimed Domestic Water Irrigated Peppers-NPK Couple Model Based on Optimized Combination Technique

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China has been utilizing wastewater to irrigate grain, cotton, and vegetable crops, as well as landscapes, for decades. Nowadays, about 1/3 of the reclaimed water is used for irrigation purposes in China. This study focuses on the coupling between the nitrogen (N), phosphorus (P), and potassium (K) content in the reclaimed domestic water irrigated peppers and capsaicin. A field experiment in the three-factor, five-level quadratic general revolving combination design was conducted for an in-depth analysis of the capsaicin content coupling model by testing the significance of the regression equation and coefficient of the regression equation. The test result shows that: (1) the factors affecting the content of capsaicin are in the following order: nitrogen fertilizer application level \( x_1 \) > phosphorus fertilizer application level \( x_2 \) > potassium fertilizer application level \( x_3 \). This arrangement is according to the effect analysis based on the established capsaicin-NPK coupling model. (2) The nitrogen-potassium interaction effectively improves the content of capsaicin. Theoretically, the content of capsaicin tends to be 0 g.kg\(^{-1}\) when both the nitrogen and potassium fertilizer application are at the lowest level, while the content of capsaicin increases with the increase of nitrogen and potassium fertilizer application. The nitrogen-potassium combination can achieve a high level of capsaicin content when both are taken on a medium scale, which can reach 0.068 g.kg\(^{-1}\) when the level of nitrogen and potassium fertilizers application reaches 120 g.kg\(^{-1}\) and 112.5 g.kg\(^{-1}\), respectively. Further, maximum capsaicin content of 0.21 g.kg\(^{-1}\) is achieved when the level of potassium and phosphorus fertilizer application reaches 120 kg.hm\(^{-2}\) and 60 kg.hm\(^{-2}\), respectively. (3) The range of the ideal target content of capsaicin in peppers irrigated with the reclaimed domestic water in China’s Ningxia Region and an optimized NPK-coupling model is developed. More specifically, based on the developed model the level of NPK fertilizers application would be 186.15 kg.hm\(^{-2}\), 71.17 kg.hm\(^{-2}\), and 122.02 kg.hm\(^{-2}\), respectively, under the condition that the content of capsaicin is greater and beyond 0.12 g.kg\(^{-1}\).

1. Introduction

Due to the fast population growth, industrialization, advancement in agricultural techniques, and urbanization, water supply, and quality have become one of the most pressing environmental issues of the twenty-first century. By the year 2055, the human population is predicted to expand from 7.3 billion to 10.2 billion. Population increase and climate change are wreaking havoc on the natural water cycle, resulting in issues such as river flow instability, spring water drying, and ecological degradation [1]. Freshwater shortages and rising food demands are two of the most pressing global issues nowadays. Climate change and socio-economic growth have had a tremendous impact on water supplies and aquatic life, causing substantial changes in global hydrological cycles [2, 3]. Furthermore, variations in water runoff, as well as changes in use and withdrawal, have disrupted surface and groundwater supplies, these trends are
anticipated to continue and will result in water scarcity in many regions. Nowadays, the increased demand for freshwater supplies, surface water contamination, water shortages, and environmental deterioration, the availability and use of unorthodox water sources has gotten a lot of attention. Alternative water sources like seawater, desalinated brackish water, and reclaimed water are becoming increasingly popular. As an alternate water supply source, people are widely using reclaimed water for agricultural irrigation [4]. Municipal wastewater that has been cleaned to fulfill specified water quality requirements and is intended to be utilized for a variety of uses is referred to as reclaimed water. Utilizing reclaimed water for irrigation not only ensures a steady supply of water for agricultural output but also saves money on chemical fertilizer. Reclaimed water irrigation has been increasingly popular in the last few decades due to benefits such as reduced disposal costs, reduced strain on other water resources, year-round dependability, nutrient restoration to crops, and reduced demand for other water resources [5].

Pepper (Capsicum annuum L.) is one of the major economic crops of China [6], which has rich contents of capsaicin, vitamin C, and minerals like calcium, phosphorus, and iron. With the sound adaptability, various varieties, a vastly growing area, and sound economic returns, pepper growing has become a pillar industry to increase the income of farmers and promote the development of the rural areas of China [7]. Kamal [8] developed an optimized combination solution through his research on the impact of different water qualities and water-fertilizer coupling on the yield, quality, and safety of peppers. The experimental results of his proposed system show that the three major factors affecting the yield of pepper are ranked in order from the most to the least as \( W > F > S \). The yield of pepper increases with the increase in irrigation quota and the proportion of reclaimed water in water for irrigation, and drops after increase with the increase in the amount of fertilizer applied. The three factors affecting the Vitamin C and soluble protein in peppers and affecting the content of capsaicin were respectively arranged in order of \( F > S > W \) and \( F > W > S \). Suge et al. [9] have conducted another study, on the impact of different phosphorus fertilizers (diammonium phosphate, calcium magnesium phosphate fertilizer, and calcium superphosphate) on the growth, quality, and yield of eggplant under the condition of reclaimed water irrigation. It shows that the reclaimed water irrigation may result in a remarkable increase in both the size and yield of eggplant and the application of calcium magnesium phosphate fertilizer may remarkably improve the yield and quality of eggplant. It also shows that the calcium magnesium phosphate fertilizer application under reclaimed water irrigation may lead to the highest content of nutrients (N, P, Ca, Mg) and the highest yield of eggplant. The study shows that the irrigation system applicable to the area has: an irrigation quota of 4860 m\(^2\)·hm\(^{-2}\), and fertilizer application volume of 1440 kg·hm\(^{-2}\) for best growth, yield, and quality eggplant under the condition of reclaimed water irrigation [10].

In another study conducted by Dadios et al. [11], they stated that the factors affecting the growth of lettuce are in the order of \( N > P > K \). Similarly, Cooke and Gething [12] found that an appropriate increase in the application of nitrogen with the interaction of nitrogen and potassium may strengthen the potash fertilizer’s effect in increasing the yield of crops. Abd-Elrahman et al. [13] stated that an appropriate increase in the amount of phosphate application may remarkably improve the yield of crops. In China, studies on the reasonable NPK combination and application focus on tomatoes and cucumbers only [14]. Research on the impacts of NPK interaction on the growth, quality, and nutrient content of vegetables has been carried out in Japan with an efficient and high-quality mode and regression model for higher yield of lettuce having been developed accordingly [15]. Research on the impacts of NPK coupling on the yield of muskmelons conducted by Ye et al. [16] by employing the three-factor, five-level quadratic general revolving combination design shows that the amount of the applied fertilizers affecting the yield of muskmelons can be ranked in order of \( P > N > K \). By taking the loose lettuces grown in Hong Kong as the test materials and adopting the three-factor, five-level quadratic general revolving combination design, Zhang et al. [17] analyzed the earlier and later stage impacts of NPK on the yield of the lettuces and found that in the earlier stage of the growth of hydroponic lettuce, the effect of NPK on the yield of the tested lettuce could be ranked in order of \( N > P > K \), which shows the interaction among such factors. By taking the seedlings of mid-subtropical Chinese fir as research objects, Zhao et al. [18] carried out a study regarding the effects of short-term warming on microbial biomass nitrogen (MBN), microbial biomass phosphorus (MBP), nitrogen, phosphorus nutrients in the soil, and coupling of nitrogen and phosphorus. Through this study, it was observed that the effect of the coupling is much influenced by the interaction between nitrogen and phosphorus. A reasonable ratio of fertilizers can help achieve the improved yield of peppers [19].

However, research concerning the effect of NPK content in reclaimed domestic water irrigated peppers on the coupling of capsaicin is limited. Keeping the limited research in the mentioned area in consideration, this study accomplishes comprehensive research on the effect of NPK content in reclaimed domestic water irrigated peppers on the coupling of capsaicin to explore this topic. The main findings and contributions of this study are listed as follows.

(i) The establishment of the Capsaicin-NPK coupling model with factors affecting the content of capsaicin in order of nitrogen fertilizer application level (\(x_1\)) > phosphorus fertilizer application level (\(x_2\)) > potassium fertilizer application level (\(x_3\)). The analysis of interaction shows that the impact of the interaction between nitrogen and phosphorus under the testing condition of the content of capsaicin is a complicated process.

(ii) Identification of the main factors affecting the yield of pepper. For example, an excessive amount of phosphorus fertilizer may lead to decreased capsaicin content while the content of capsaicin may be efficiently improved when some nitrogen is added.
with a low amount of phosphorus. Further, the interaction between nitrogen and potassium may effectively improve the content of capsaicin.

(iii) The optimal combination scheme of nitrogen, phosphorus, and potassium in the content range of capsaicinoids: the applied amount of NPK fertilizers is 186.15 kg·hm$^{-2}$, 71.17 kg·hm$^{-2}$, and 122.02 kg·hm$^{-2}$, respectively, under the circumstances of the content of capsaicin being greater than 0.12 g·kg$^{-1}$. All the experimental and analysis results show the effectiveness of the proposed NPK-coupling model.

The remaining paper is arranged as follows; section 2 illustrates the material and methods, section 3 represents the experimental results and analysis, and section 4 describes the discussion of the experimental results attained in section 3. Finally, section 5 concludes the overall theme and findings of this study.

2. Material and Methods

2.1. Background Information on the Test Area. The test was conducted at the Reclaimed Water Test and Demonstration Base of Yingli Group Ltd in Shapotou District, Zhongwei City, Ningxia (37°34′N,105°10′E) from 2019 to 2021. Being located in the hinterland of China, the test area is a semi-arid region that features a typical continental monsoon climate and desert climate with strong wind and sandstorms, drought due to limited volume of rainfall, the big difference in temperature during day and night, remarkable water evaporation during the daytime, short summer and long winter, with most of the rainfall taking place during the period from June to August. In the test area, the annual volume of rainfall is 179.6 mm, accounting for 60% of the total volume of rainfall year-round. The annual volume of evaporation is 1829.6 mm, the total number of sunshine hours is 2800, the total annual volume of solar radiation is 5872.9 kJ cm$^{-2}$, the average temperature a year-round is 8.8°C, large difference of temperature even during the daytime to range from 10 to 16°C with the average annual temperature ranging between 7.3 and 9.5°C, the terrain of the field of the test is plain with well-balanced fertility. Further, the texture of the field is loam, the field water-holding rate is 23.5% (accounting for % of dry soil weight), and the soil dry bulk density is 1.43 g/cm$^3$.

2.2. Test Design. The test is designed to adapt the three-factor, five-level quadratic general revolving combination design. It is determined in line with the actual condition of the agricultural production activities in the area of the test that the volume of N, P, and K fertilizers (including the original fertility of the soil) serve as the test factors ($Z_j$), for each of which, five levels are set. The number of test treatments ($n$): 20; the zero level ($Z_{j0}$) and the interval of changes ($\Delta_j$) are as follows:

$$Z_{j0} = \frac{Z_{j1} + Z_{j2}}{2},$$

$$\Delta_j = \frac{Z_{j2} - Z_{j1}}{\gamma}$$

As seen in the equations above that $Z_{j2}$ and $Z_{j1}$ represent the upper and lower limit of the factors respectively; $J$ stands for the number of the factors; $j = 1, 2, 3; \gamma$ serves as an asterisk and is determined according to the requirements of the universal rotation of quadratic regression; that is: $\gamma = 2p/4$ (with $p$ representing the number of factors.). The level code obtained after the linear change of the factor $Z_j$ is given as follows:

$$X_j = \frac{Z_j - Z_{j0}}{\Delta_j}.$$ 

Equation (2) shows that the natural variable $Z_j$ turns into a unitless canonical variable $X_j$ with the factors and levels after encoding being: $-1.682, -1, 0, 1, 1.682$ (see Table 1).

2.3. Test Implementation. In this study, the treatments concerning the time of sowing, the density of planting, forms of planting, and the original fertility of soil are the same. Following are some of the characteristics that were kept into consideration in the test implementation process; Technology adopted: beneath-mulch drip irrigation technique; Material adopted: embedded drip belts; Dripper spacing: 30 cm; Drip belt spacing: 45 cm. Pre-planting irrigation was carried out before planting on 31 May 2018 with a set drip irrigation quota of 96 m$^3$·hm$^{-2}$, four irrigations per month; total number of irrigations: 12; quota of irrigation: 1152 m$^3$·hm$^{-2}$. Fertilizer application was performed on 01 July and 01 August respectively. Different fertilizers of ammonia, urea, and potassium were blended according to the set level (of N180-P$\_2$O$\_5$90-K$\_2$O112.5 kg·hm$^{-2}$). Sampling for the yield survey was conducted on 22 September 2018. Harvesting was accomplished on 23 September with the quality of pepper plants, dry matters, and the economic output of peppers having been surveyed and determined.

2.4. The Main Features Observed in the Implementation Process. The main features and items that are of utmost importance and observed in this study include the height of pepper plants, moisture content and bulk density of soil, the water-holding capacity of the field, capsaicin, and total substances of capsaicin, vitamin C, and yield.

3. Experimental Results and Analysis

3.1. Establishment of a Coupled Model of Capsaicin and NPK. Contents of capsaicin obtained through tests are displayed in Table 2 (Column 12). Statistical analysis of the capsaicin contents obtained (g·kg$^{-1}$) was carried out with DPS based on a three-factor, five-level quadratic general revolving combination design. The combined capsaicin-NPK regression model of quadratic general rotation obtained through
the regression equation obtained is usable. Therefore, the content of capsaicin (in fresh weight) in peppers estimated and measured with the coupled regression model is highly reliable. Results of calculation through the $t$-test on the model are shown in Table 3.

The above results show that the constant terms, the primary terms of phosphorus and potassium, and the quadratic terms of phosphorus have reached the level of extreme significance with the interaction terms of nitrogen and phosphorus reached to a significance level. The primary terms of nitrogen, the terms of interaction between nitrogen and potassium, and the terms of interaction between phosphorus and potassium are not significant.

### 3.3. Capsaicin-NPK Coupling Model Analysis

#### 3.3.1. Effect of Principal Factors

As the partial regression coefficient is not affected by the amount and unit of factor value after the change in dimensionless linear encoding or

#### Table 1: Codes of factors and levels.

<table>
<thead>
<tr>
<th>Factors</th>
<th>Amount of nitrogen ($z_1$) (kg.hm$^{-2}$)</th>
<th>Amount of phosphorus P$_2$O$_5$ ($z_2$) (kg.hm$^{-2}$)</th>
<th>Amount of potassium K$_2$O ($z_3$) (kg.hm$^{-2}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Levels</td>
<td>1.682</td>
<td>240</td>
<td>120</td>
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<tr>
<td>1</td>
<td>1</td>
<td>215.7</td>
<td>107.8</td>
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<tr>
<td>0</td>
<td>180</td>
<td>90</td>
<td>112.5</td>
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<tr>
<td>−1</td>
<td>144.3</td>
<td>72.2</td>
<td>90.2</td>
</tr>
<tr>
<td>−1.682</td>
<td>120</td>
<td>60</td>
<td>75</td>
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</table>

#### Table 2: Structure matrix ($X$) of three-factor quadratic general revolving combination design and tested contents of capsaicin.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Constant terms $x_0$</th>
<th>N $x_1$</th>
<th>P $x_2$</th>
<th>K $x_3$</th>
<th>N-P $x_1x_2$</th>
<th>N-K $x_1x_3$</th>
<th>P-K $x_2x_3$</th>
<th>Nitrogen quadratic term $x_1^2$</th>
<th>Phosphorus quadratic term $x_2^2$</th>
<th>Potassium quadratic term $x_3^2$</th>
<th>Capsaicin $y$ (g.kg$^{-1}$)</th>
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<td>1</td>
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<td>−1</td>
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<td>0.060</td>
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<td>1</td>
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</table>

statistics of the contents of capsaicin shown in Table 2 is as follows:

$$y = 0.068 + 0.0026x_1 - 0.0265x_2 - 0.0198x_3$$

$$- 0.0093x_1^2$$

$$- 0.00272x_2^2 - 0.0122x_2^2 + 0.0149x_1x_2 - 0.0085x_1x_3$$

$$+ 0.0077x_2x_3.$$  

(3)

According to the equation: $y$ represents the content of capsaicin (g.kg$^{-1}$); $x_j$ represents the dimensionless variables after linear transmission; $j = 1, 2, 3$. 

### 3.2. Test of Capsaicin-NPK Coupling Model

Regression and mismatch tests were carried out on the proposed model. The regression fitting Fr value obtained through calculation is 4.27 with the level of significance level $p$ being 0.005 (less than 0.05), and the mismatch test value FLF value being 1.26, less than $F_0.05 = 3.69$ which is not significant, showing that the regression equation obtained is usable. Therefore, the content of capsaicin (in fresh weight) in peppers estimated and measured with the coupled regression model is highly reliable. Results of calculation through the $t$-test on the model are shown in Table 3.

The above results show that the constant terms, the primary terms of phosphorus and potassium, and the quadratic terms of phosphorus have reached the level of extreme significance with the interaction terms of nitrogen and phosphorus reached to a significance level. The primary terms of nitrogen, the terms of interaction between nitrogen and potassium, and the terms of interaction between phosphorus and potassium are not significant.
after it has actually become standardized and the amount of value can now directly reflect the extent to which the variable impacts the content of capsaicin, it is therefore concluded that factors affecting the content of capsaicin during the process of the test can be ranked in order of the amount of phosphorus \((x_2)\) > amount of potassium \((x_3)\) > amount of nitrogen \((x_1)\).

3.3.2. Effect of the Single Factor. Fix two of the three factors, nitrogen, phosphorus, and potassium, in the regression model at level zero to obtain the regression submodels of a single factor on capsaicin content as shown above.

**Nitrogen:**
\[
y_1 = 0.068 + 0.0026x_1 - 0.0093x_1^2. \tag{4}
\]

**Phosphorus:**
\[
y_2 = 0.068 - 0.0265x_2 + 0.0227x_2^2. \tag{5}
\]

**Potassium:**
\[
y_3 = 0.068 - 0.0198x_3 - 0.0122x_3^2. \tag{6}
\]

According to the partial regression submodels above, such results as \(x_1 = 0.141, x_2 = 0.4868, \) and \(x_3 = -0.809\) can be obtained when \(dy_1/dx_1 = 0, dy_2/dx_2 = 0, \) and \(dy_3/dx_3 = 0.\) And the content of capsaicin reaches the highest values of \(y_1 = 0.0682 \text{g/kg and } y_3 = 0.076 \text{g/kg, respectively, when } x_1 = 0.141 \text{ and } x_3 = -0.809.\)

The partial regression submodels above show that the predicted values of capsaicin content under different levels of a single factor can be obtained respectively when other factors are at 0 (as shown in Table 4).

We can see that the content of capsaicin is an open downward trend during the process where the volume of nitrogen application rises from 120 kg.hm\(^{-2}\) (level -1.682) to 240 kg.hm\(^{-2}\) (level 1.682) throughout the test but shows a trend of decrease when the volume of phosphorus application climes from 60 kg.hm\(^{-2}\) (level -1.682) up to 120 kg.hm\(^{-2}\) (level 1.682). The content of capsaicin is also in an open downward trend during the process where the volume of potassium application rises from 75 kg.hm\(^{-2}\) (level -1.682) to 150 kg.hm\(^{-2}\) (level 1.682).

It can also be seen that the content of capsaicin rises from 0.037 g.kg\(^{-1}\) to 0.061 g.kg\(^{-1}\) when the volume of nitrogen application increases from 120 kg.hm\(^{-2}\) (level -1.682) to 180 kg.hm\(^{-2}\) (level 0) with the increase in yield reaching 0.0004 g.kg\(^{-1}\) when the unit nitrogen application increases. Therefore, it is concluded that the content of capsaicin comes to the highest level under the test circumstance when the applied amount of nitrogen fertilizer reaches 180 kg.hm\(^{-2}\), but the content starts dropping when more nitrogen is applied.

The content of capsaicin shows a trend of decrease from 0.189 g.kg\(^{-1}\) down to 0.061 g.kg\(^{-1}\) when the level of phosphorus application rises from 60 kg.hm\(^{-2}\) (level -1.682 ) to 90 kg.hm\(^{-2}\) (level 0) and drops down to 0.0043 g.kg\(^{-1}\) when the unit phosphorus fertilizer application is increased, which clearly shows that the content of capsaicin is at its highest when nitrogen level is at 60 kg.hm\(^{-2}\) and shows that the increase in phosphorus application leads to the decrease in the content of capsaicin.

The content of capsaicin shows a trend of rising from 0.01 g kg\(^{-1}\) to 0.065 g kg\(^{-1}\) when the potassium fertilizer amount increases from 75 kg.hm\(^{-2}\) (level -1.682 ) to 134.8 kg.hm\(^{-2}\) (level +1). When the amount of potassium applied increases, the increased amount of yield is 0.0092 g.kg\(^{-1}\), which clearly shows that an increase in the amount of potassium fertilizer to a certain extent may result in an increased content of capsaicin. In general, phosphorus fertilizer has a significant impact on the content of capsaicin, that is, the content of capsaicin will be 0.037 g.kg\(^{-1}\), 0.1 g.kg\(^{-1}\), and 0.0628 kg hm\(^{-2}\) accordingly when the levels of NPK fertilizer application are all at 120 kg.hm\(^{-2}\).

3.3.3. Interaction between Different Factors. It is discovered through the in-pair analysis of the interactions between the test results that under the circumstance of the test, all the factors interact with one another.

\[
y_1 = 0.068 + 0.0026x_1 - 0.0265x_2 + 0.0227x_2^2 - 0.0093x_1^2 + 0.00149x_1x_2,\tag{7}
\]

\[
y_2 = 0.068 + 0.0026x_1 - 0.0198x_3 - 0.0122x_3^2 - 0.0085x_1x_3 - 0.0122x_3^2 - 0.0085x_1x_3,\tag{8}
\]

\[
y_3 = 0.068 - 0.0265x_2 - 0.0198x_3 + 0.0272x_2^2 - 0.0122x_3^2 + 0.0077x_2x_3.\tag{9}
\]

From Figure 1 it can be observed that the impact of the interaction between nitrogen and phosphorus during the testing process on the content of capsaicin is a complicated process. Excessive application of phosphorus fertilizer may lead to decreased capsaicin content, while the content of capsaicin may be efficiently improved to reach 0.217 g.kg\(^{-1}\) when a medium amount of nitrogen plus a low amount of phosphorus is added to it.
Figure 2 shows that during the testing process the interaction between nitrogen and potassium can effectively improve the content of capsaicin. When both the level of nitrogen and potassium fertilizer application are at their lowest, the content of capsaicin will theoretically tend to be $0 \text{ g.kg}^{-1}$. On the other hand, with an increase in both the level of nitrogen and potassium fertilizer, the content of capsaicin increases accordingly. The maximum content of capsaicin may be achieved under the circumstance of the application of fertilizer with a medium amount of nitrogen plus a low amount of phosphorus. Such content may reach $0.068 \text{ g.kg}^{-1}$ when the applied amount of nitrogen and potassium is $120 \text{ g.kg}^{-1}$ and $112.5 \text{ g.kg}^{-1}$, respectively.

![Figure 1: Interaction between nitrogen and phosphorus.](image)

<table>
<thead>
<tr>
<th>Levels</th>
<th>Prediction under nitrogen application (g.kg$^{-1}$)</th>
<th>Prediction under phosphorus application (g.kg$^{-1}$)</th>
<th>Prediction under potassium application (g.kg$^{-1}$)</th>
</tr>
</thead>
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<td>0.1894</td>
<td>0.0667</td>
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<td>0.1216</td>
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<td>0.0687</td>
<td>0.0360</td>
</tr>
<tr>
<td>1.682</td>
<td>0.0460</td>
<td>0.1004</td>
<td>0.0002</td>
</tr>
</tbody>
</table>

**Table 4: Predicted values of Capsaicin in Pepper under the circumstance of NPK application.**
Figure 3 shows that under certain circumstances during the process of the test, the content of capsaicin further increases with the decrease in the applied amount of phosphorus with the highest volume of 0.21 g.kg$^{-1}$ of capsaicin content being obtained when the amount of potassium and phosphorus fertilizer used reaches 120 kg.hm$^{-2}$ and 60 kg.hm$^{-2}$, respectively. Subsequently, the content drops somehow with the increase in phosphorus fertilizer.
showing the content of capsaicin in peppers greater than 0.12g.kg$^{-1}$ having been obtained. As shown in Table 5.

### 4. Discussion

The conducted tests focus on the analysis of the quadratic regression model of the yield factors through the three factors of nitrogen (N), phosphorus (P), and potassium (K). Factors affecting the content of capsaicin are ranked in order of applied amount of nitrogen ($x_1$) > applied amount of phosphorus ($x_2$) > applied amount of potassium ($x_3$), this rank is obtained through the analysis of the effects of the main factors. In section 3 we observed that, under the reclaimed domestic water irrigation, the NPK influence on the content of capsaicin decreases successively and the treatment of the low-amount application and zero application of NPK fertilizers may result in the premature senility and weak growth of peppers [20]. The optimal combination scheme of N, P, and K in the content range of capsaicinoids goes like this: the applied amount of NPK fertilizers is 186.15 kg.hm$^{-2}$, 71.17 kg.hm$^{-2}$, and 122.02 kg.hm$^{-2}$, respectively, under the condition of the content of capsaicin being greater than 0.12 g.kg$^{-1}$. The experimental results obtained from the research show that the amount of fertilizer application is lower than the guiding amount proposed by Huang et al. [21, 22], which may be due to the condition of soil fertility and/ or the variety of the peppers. The impact of the interaction between N and P under the test conditions on the content of capsaicin is a complicated process.

Excessive application of phosphorus fertilizer may lead to decreased capsaicin content; however, the content of capsaicin may be efficiently improved to reach 0.217 g.kg$^{-1}$ when a medium amount of nitrogen plus a low amount of phosphorus is used. During the process of the test, the content of capsaicin will further increase with the decrease in the applied amount of phosphorus, and the highest volume of 0.21 g.kg$^{-1}$ of capsaicin content is obtained when the amount of potassium and phosphorus fertilizer used reaches 120 kg.hm$^{-2}$ and 60 kg.hm$^{-2}$, respectively. Subsequently, however, the content of capsaicin drops somehow with the increase in phosphorus fertilizer. This is because an increase in nitrogen level may lead to an increase in nitrogen metabolism, which has a positive effect on the synthesis of capsaicin as a nitrogen-containing compound. The effects of phosphorus and potassium on capsaicin synthesis present themselves in the promotion of the activity of protease and the promotion of the activity and absorption of nitrogen respectively. Therefore, under the condition of reclaimed water irrigation, attention should also be paid to the NPK coupling amount, which will not only result in an improved yield and quality of pepper but also well-relieved the pollution to the environment for sustainable development.

### 5. Conclusion

Nowadays, the increased demand for food, fresh water supplies, surface water contamination, water shortages, environmental deterioration, and the availability and use of unorthodox water sources have gotten a lot of attention. Under the circumstances, alternative water sources like seawater, desalinized brackish water, and reclaimed water are becoming increasingly popular. This study accomplishes comprehensive research on the effect of NPK content in reclaimed domestic water irrigated peppers on the coupling of capsaicin. We observed that the factors affecting the content of capsaicin are in the order of nitrogen fertilizer application level ($x_1$) > phosphorus fertilizer application level ($x_2$) > potassium fertilizer application level ($x_3$) having obtained through analysis of the effects of the main factors. The interaction analysis shows that the impact of the interaction between nitrogen and phosphorus under the condition of test on the content of capsaicin is a complicated process. From the analysis results, it is obvious that the excessive use of phosphorus fertilizer can decrease the content of capsaicin, while it can be increased when a medium amount of nitrogen plus a low amount of phosphorus is used. In addition, when both the level of nitrogen and potassium fertilizer application is at their lowest, the content of capsaicin will theoretically tend to be 0 g.kg$^{-1}$. On the other hand, with an increase in both the level of nitrogen and potassium fertilizer, the content of capsaicin increases accordingly. The maximum content of capsaicin is achieved with the use of a small amount of phosphorus and a medium amount of nitrogen. When we use 120 g.kg$^{-1}$ amount of nitrogen and 112.5 g.kg$^{-1}$ amount of potassium the content

![Table 5: Optimization scheme under the condition of capsaicin content greater than 0.12 g.kg$^{-1}$](image)
of capsaicin may reach 0.068 g kg\(^{-2}\). During the testing process, the content of capsaicin further increases with the decrease in the applied amount of phosphorus, and the highest volume of 0.21 g kg\(^{-1}\) of capsaicin content is obtained when the amount of potassium and phosphorus fertilizer used reaches 120 kg hm\(^{-2}\) and 60 kg hm\(^{-2}\), respectively. From the analysis results it is obvious when the applied amount of the nitrogen is 186.15 kg hm\(^{-2}\), phosphorus is 71.17 kg hm\(^{-2}\), and potassium is 122.02 kg hm\(^{-2}\), it is considered the optimal combination scheme of the NPK model, resulting in the yield of capsaicin greater than 0.12 g kg\(^{-1}\).

Data Availability

The data used and analyzed during the current study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

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