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# Foliar and Fertigation Application of NPK Fertilizers Impact on Growth, Seed Yield and Yield Components of Safflower (Carthamus tinctorius L.)

**KEY WORDS:**

Nutrient, methods of NPK application, dry matter yield, seed yield, locations

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## ABSTRACT

Safflower (Carthamus tinctorius L.) is an annual oil crop that belongs to the Asteraceae family. The experimental studies were conducted at two different research stations in the Kurdistan Regional of Iraq to determine various liquid NPK application methods on the growth, yield, and yield components of three safflower varieties. The experimental design was a complete block design under split-plot system with three replications. NPK application methods (Foliar, Fertigation, Foliar + Fertigation) and no fertilizer application are the main plots. While three safflower varieties (Iden, AL-Shamia, and Zaafarani) as sub-plots. Foliar NPK application had the highest dry matter yield and seed yield of 29.544ton ha-1 and 7.185ton ha-1, respectively, at the average of both locations. Zaafarani safflower variety recorded the maximum dry matter yield and seed yield of 22.204ton ha-1 and 4.794ton ha-1, respectively, at the average of both locations. However, the statistical analysis for both locations' average shows non-significant differences between Iden and Zaafarani varieties have the highest performance for seed yield under foliar NPK application. Based on the average effectiveness of the different methods of applying NPK and safflower varieties on most components of growth, yield, and yield components, the order was as follows: Foliar > Foliar + Fertigation > Fertigation > Control. While for safflower varieties, it was as follows: Zaafarani > Iden > AL-Shamia. The results indicated that the number of capitula plant-1 is an essential character in safflower's seed yield.





## INTRODUCTION

Safflower (*Carthamus tinctorius* L.) is an annual winter-spring oil crop, highly branched, herbaceous thistles that belong to the Asteraceae family. Safflower usually intended to produce seeds for oil extraction, which has high quality as human food and potential for biofuel production. Also, it makes a good livestock forage during vegetative growth (Dordas and Sioulas, 2008; Danieli et al. 2011; Rastgou et al. 2013: Shahrokhnia and Sepaskhah, 2016; Pasandi et al. 2018). It is a long-season crop, extracting water from the soil for an extended period than cereal crops. The long taproot allows it to explore deeper soil layers, enhancing its ability to extract water and nutrients that are not available for most crops. This characteristic makes this plant more resistant to drought (Herdrich, 2001; Mohammadi, 2001; Bagheri and Sam-Dailiri, 2011). Safflower is one of the crucial oilseeds crops worldwide. The seed oil content ranges from 20 to 40 %, depending on genotypes and growth conditions (Gouzy et al. 2016; Liu et al. 2016).

Safflower requires an adequate supply of nutrients for its full production potential even under limiting moisture conditions (Rao, 1985; Kubsad et al. 2001). Nitrogen is one of the most required nutrients by plants since it is part of proteins, enzymes, chlorophyll, nucleic acids, and hormone synthesis (Taiz and Zeiger, 2013). According to Sabbagh et al. (2012), safflower is more

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responsive to nitrogen (N) than other nutrients. It requires a more considerable amount of this element during its vegetative stage. Phosphorus (P) is an essential macro plant nutrient needed in larger quantities than other elements, followed by nitrogen. Potassium (K) is critical for activating the enzyme, protein synthesis, photosynthesis, and photosynthates. (Pettigrew, 2008; Xu et al. 2011). However, Hussien and Wuhaib, (2010) and Palizdar et al. (2011) observed increases in biometric features and higher yields in safflower crops with more significant availability of potassium.

For a more accurate and convenient application of fertilizers on large farms, liquid fertilizers offer certain advantages. Farmers do not need to carry fertilizer bags; they rely on pumping. Sprinklers can be used to protect crops, but suspensions require special nozzles. Macronutrient affects primary and secondary metabolism in plants, which ultimately results in seed yield enhancement in crop plants (Malik et al. 2011; Nadim et al. 2011; Malik et al. 2012; Malik et al. 2013a; Malik et al. 2013b). The most effective way for the growth of safflower in semi-arid conditions with high efficiency is when and how to apply the fertilizers properly. Crop productivity relies on major NPK fertilizers, and the balanced application of NPK fertilizer rates plays a great deal in safflower production. Igbadun et al. (2006) showed that the crop yield response depended on the amount of water applied at different crop development stages than the overall seasonal water applied. Jaga, (2013) revealed that all significant macronutrients (N, P, K, Ca, Mg, S) is essential for plant development.

The method of fertilizers application is an essential component of good agricultural practices. For acceptable farming practices, the farmer chooses the timing and quality to use as much as possible of the nutrient. The two common methods are Foliar fertilization and Fertigation (Álvarez-Fernández et al. 2004; Bhat et al. 2007). Foliar fertilizer application is a technique using which the nutrients can be provided to crop plants in a spray where the nutrients readily reach the actual activity (Kołota and Osińska, 2000). It avoids the fixation of nutrients in the soil. The application of fertilizers with irrigation water (Fertigation) has several advantages over traditional methods. The time and rate of fertilizer applied can be regulated precisely (Gurusamy et al. 2011; Kumar et al. 2011). Foliar fertilizer application results in better nutrients absorption by the plants than the rest of the methods, thus increasing fertilizer use efficiency (Kamel et al. 1987).

Safflower genotypes varied significantly in plant height, the number of branches and heads plant$^{-1}$, seed index, seed yield per plant and hectare, seed oil content, and oil yield (Dahiya and Singh, 1980; Ali and Osman, 2004; EL-Far et al. 2010). The yield and yield components may be affected by genotype, ecology, morphology, physiology, and fertilization (Coşge et al. 2007). This study's objective was to evaluate and use a proper technology and study the effects of different methods of liquid NPK fertilizer application on some growth and yield characters of three safflower varieties under a semi-arid condition.

## MATERIALS AND METHODS

### Experimental site and climate condition

Two field experiments were conducted during the winter of 2017 at two different locations. The first location was at the Kanipanka Agricultural Research Station (latitude: 35° 22' 22″ N, Longitude: 045° 43' 22″ E, altitude: 548 masL) in Sharazoor intermountain 35 km east of Sulaimani. At the same time, the second location was at Qlyasan, the farm of Biotechnology and Crop Science Department, College of Agricultural Engineering Sciences, the University of Sulaimani, located at (latitude: 35° 34' 17″ N, Longitude: 045° 22' 00″ E, altitude: 757 masL). The climate is a semi-arid environment; hot and dry in summer, cold and wet in winter, and a rainy season from autumn to winter. During that period, the temperature ranged from 11℃ to 26℃. (Kurdistan Regional Government, 2018; *see Table 1*).

**Table (1) Agrometeorological parameters at Kanipanka and Qlyasan locations 2017**

| Locations | Month | Air Temperature °C | | Precipitation (mm) |
|---|---|---|---|---|
| | | Minimum | Maximum | |
| Kanipanka | December | 3.7 | 11.5 | 115.4 |
| | January | 1.9 | 11.1 | 51.7 |
| | February | 1.4 | 11.8 | 87.1 |
| | March | 7.4 | 16.9 | 113.5 |
| | April | 11.2 | 23.6 | 70.8 |
| | May | 15.8 | 33.5 | 19.0 |
| | June | 21.0 | 39.7 | 0.0 |
| | July | 26.7 | 44.6 | 0.0 |
| Qlyasan | December | 2.0 | 18.0 | 158.0 |
| | January | 1.4 | 11.1 | 36.5 |
| | February | -0.26 | 13.1 | 206.1 |
| | March | 7.5 | 17.7 | 68.6 |
| | April | 11.0 | 34.0 | 34.2 |
| | May | 13.0 | 40.0 | 17.2 |
| | June | 21.0 | 47.0 | 0.0 |
| | July | 28.0 | 48.0 | 0.0 |

## Soil sampling and analysis

The soil samples were collected at a depth of 0-60 cm for laboratory analysis at each location. They were air-dried gently, crushed, and tested for physical and chemical properties. Details of soil properties are shown in (*Table 2*).

***Table 2.*** *Physicochemical properties of the soil samples for locations of the experimental field*

| Physicochemical properties | | Locations | |
|---|---|---|---|
| | | **Kanipanka** | **Qlyasan** |
| Particle size distribution (g $kg^{-1}$) | Sand | 36 | 107 |
| | Silt | 529 | 435 |
| | Clay | 435 | 458 |
| | Texture class | Silty Clay | Silty Clay |
| Total Nitrogen (mg $kg^{-1}$) | | 1.03 | 1.07 |
| Available Phosphate (mg $kg^{-1}$) | | 7.2 | 6.28 |
| Soluble Potassium (mmol $L^{-1}$) | | 0.06 | 0.06 |
| PH | | 7.70 | 7.59 |
| EC (dS $m^{-1}$) | | 0.22 | 0.49 |
| Organic matter (g $kg^{-1}$) | | 14.8 | 22.4 |
| $CaCO_3$ (g $kg^{-1}$) | | 208.3 | 304.3 |

## Fertilizer Placement Methodology

Liquid NPK fertilizer (20-20-20), EC Fertilizer: Guaranteed Content (W/W) %. Nitrogen (N) 20% Urea ($CH_4N_2O$), Phosphorus (P) 20% Phosphoric acid ($H_3PO_4$), and Potassium (K) 20% Potassium Chloride (KCl). In the case of Foliar application, liquid NPK fertilizers in the amount of three liters were mixed with 1000 liters of water, which is adequate to cover one hectare as recommended. It was carried out when wind speed was minimal. Fertigation application, carried out by mixing thirty liters of NPK in water, as recommended, and applied to the irrigation water. This rate was sufficient to cover one hectare. The third purposes are the combination of (half-dose Foliar NPK application + half dose Fertigation NPK application). Finally, zero NPK application (Control): This treatment is no fertilizer added to the plot. Two applications of NPK were performed, starting at 45 days after sowing (DAS) and ending at 105 DAS, when flowering began.

**Safflower variety**

Safflower varieties (Iden, AL-Shamia, and Zaafarani) used in this study were obtained from the Agricultural Research Station, Ministry of Agriculture and Water Resources in Sulaymaniyah, Kurdistan Regional Government Iraq.

**Experimental design and treatments**

The experiment was laid out in Split Plot Design with three replicates. Four methods of applying NPK fertilizer (foliar, Fertigation, foliar + Fertigation, and NPK zeros) are the main plots. Split plots for three safflower varieties (Iden, AL-Shamia, and Zaafarani), consisting of 36 experimental units. The sub-plot was 1.5 m by 0.90 m in size; each consisted of three rows spaced at 0.30 m with a plant distance of 0.15 m. Safflower seeds were hand-planted in line at a depth of 3 to 5 cm during January 10th, 2017, at the first location (Kanipanka) and December 31st, 2016, at the second location (Qlyasan). After completion of germination, seedlings thinned out to one plant hole$^{-1}$. Fertilization and other crop management practices were carried out manually.

**Traits evaluated**

The variables of fresh stem weight, dry leaf weight, and the number of leaves plant$^{-1}$ were determined by the harvest of four random plants from the middle rows were evaluated before the harvest during the physiological stage of maturity. Five fully mature plants were harvested randomly for yield and yield components when seed yield was adjusted in each plot to 10% moisture. The plant was harvested at 187 DAS at the first location (Kanipanka) and 193 DAS at the second location (Qlyasan).

**Statistical analysis**

All data were subjected to statistical analysis by the technique of variance of the split-plot design using XLSTAT (2016). For a direct comparison of treatments, the less significant difference tests (LSD) were used at levels of 0.05. For testing the main effects of NPK fertilizer application on safflower varieties, the data were subjected to analysis of variance (ANOVA). Principal Component Analysis (PCA) was performed to show the relationship between the treatments and studied characters.

## RESULTS AND DISCUSSION

**Vegetative Traits** The results from both locations and their average showed that different NPK application methods were highly significantly affected the growth of safflower (Appendix 1). NPK are the essential nutrients for safflower growth, influencing all plant parts' dry weight, hence the dry matter yield. The increase in dry matter yield in response to different NPK application methods was accompanied by increasing the dry weight of stem, leaf, capitula, and the number of leaves at both locations and their average. The principal companion analysis for growth characters at different NPK applications was 99.99%, at the average of both locations (Figure 1). The biplot shows the variation obtained from the first and second factors of the four NPK applications' significant effects on safflower growth and it is characters. Foliar NPK application was superior and significantly impacted dry stem weight, dry leaf weight, dry capitula weight, number of leaves plant$^{-1}$, and dry matter yield. Dry matter yield recorded the maximum value of 29.544ton ha$^{-1}$ with the NPK foliar application compared to 18.694-, 22.038-, and 14.706ton ha$^{-1}$ for the treatments Fertigation, Foliar + Fertigation, and Control application, respectively (Table 3). The Foliar NPK application showed a strong response to the above-ground dry weight and the number of leaves compared to the other treatments, especially control, causing an increase in dry matter yield. However, N and P increased the number of branches and leaves, the assimilation and transpiration rates, stomatal conductance, chlorophyll index, and leaf area index (Arani et al. 2011: Golzarfar et al. 2011; Mohamed et al. 2012; Singh and Singh, 2013; Bonfim-Silva et al. 2015). Among the macronutrients, N, P, and K positively influence dry matter partitioning in leaves and stems and is essential for plant growth and development (Padmavathi and Lakshmamma, 2003; Pettigrew, 2008; Dordas and Sioulas, 2009). The present study demonstrated that the foliar NPK application fertilizers significantly improved the growth characteristics of safflower compared to the rest of the treatments.

**Table (3) Effect of NPK Applications on some safflower growth characters at the average of both location**

| NPK applications methods | Dry Stem Weight (g) | Dry Leaf Weight(g) | Dry Capitula Weight (g) | No. of Leaves Plant$^{-1}$ | Dry Matter Yield (ton ha$^{-1}$) |
|---|---|---|---|---|---|
| Foliar | 73.635 a | 15.239 a | 44.076 a | 162.148 a | 29.544 a |
| Fertigation | 49.843 b | 10.645 c | 23.638 c | 94.090 c | 18.694 c |
| Foliar & Fertigation | 56.423 b | 12.063 b | 30.685 b | 113.963 b | 22.038 b |
| Control (No NPK) | 41.734 c | 8.788 d | 15.656 d | 74.810 d | 14.706 d |
| LSD 0.05 | 7.262 | 1.061 | 3.988 | 11.146 | 2.225 |

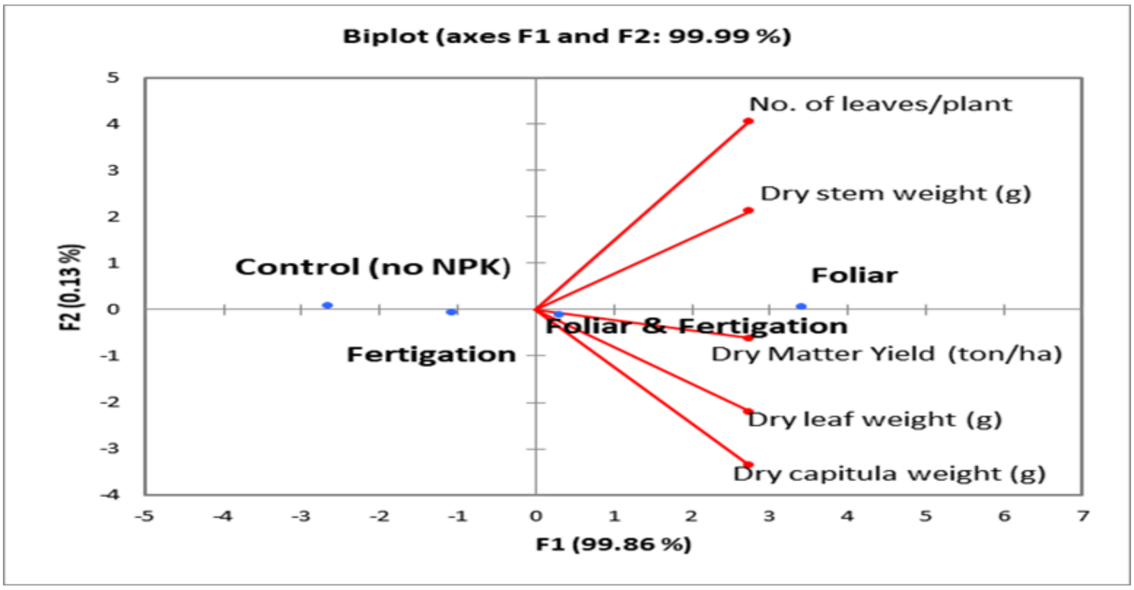



Figure 1. PCA plot showing the effect of NPK application on growth character at the average of both locations

Data in (Appendix 1) showed significant differences among safflower varieties in stem, leaf, capitula dry weights, the number of leaves, and dry matter yield at both locations and averages, except the number of leaves at the first location. As shown in Table 4 and Figure 2, the average of both locations and the principal component analysis were accounted for 100% of the total variation for different safflower varieties. Zaafarani variety recorded significantly higher dry matter yield than the Iden variety. Altogether, there was no significant difference between Zaafarani and Al-Shamia varieties for almost all the traits except the dry capitula weight, which Iden variety showed the highest value. These results may be due to the genotypic behavior combined with the environmental conditions, which may be suitable for the Zaafarani variety than the other two. Zaafarani variety predominated the Iden variety by 11.57% for the dry matter yield. In previous studies, it has been established that the safflower's growth habit is variety-dependent (Mirza et al. 2018).

**Table (4) Effect of safflower varieties on some growth character at the average of both locations**

| Safflower varieties | Dry Stem Weight (g) | Dry Leaf Weight (g) | Dry Capitula Weight (g) | No. of Leaves Plant$^{-1}$ | Dry Matter Yield (ton ha$^{-1}$) |
|---|---|---|---|---|---|
| Iden | 47.626 b | 9.860 b | 30.869 a | 102.260 b | 19.634 b |
| Al-Shamia | 59.833 a | 12.427 a | 26.287 c | 119.541 a | 21.899 a |
| Zaafarani | 58.767 a | 12.765 a | 28.386 b | 111.957 a | 22.204 a |

| | | | | | |
|---|---|---|---|---|---|
| LSD 0.05 | 5.160 | 0.707 | 1.651 | 9.120 | 1.424 |

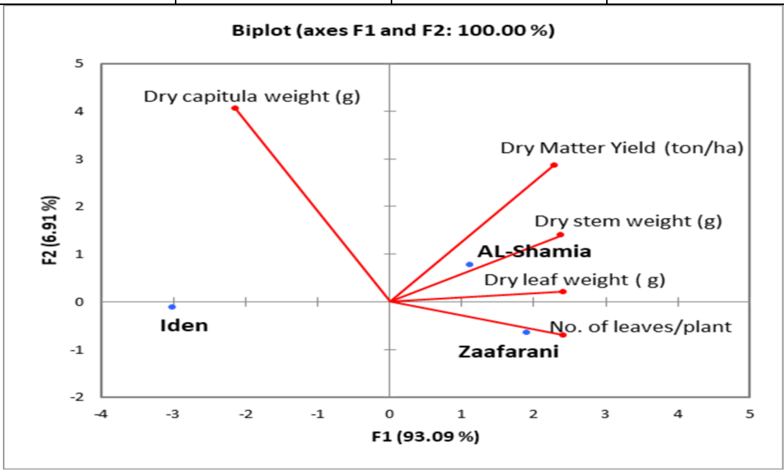



Figure 2. PCA plot showing the effect of safflower varieties on growth character at the average of both locations

The interaction between NPK application methods and safflower varieties on growth character is shown in (Appendix 1) for both locations and their average. At the first location, dry leaf and dry capitula weight recorded a significant value. While at the second location, the interaction's highly significant effect was noticed for the dry capitula weight and dry matter yield of safflower. Interaction between NPK application methods and safflower varieties did not show any significant differences for the dry stem weight, the number of leaves plant$^{-1}$ at both locations, and their average. Although no significant differences were identified between NPK application and varieties for the dry leave weight at the second location and their average.

In contrast, Dry matter yield recorded a non-significant effect at the first location and the average of both locations. As reported in (Appendix 1), the dry capitula weights were highly significantly different at the average of both locations for the interaction between NPK application and varieties. The statistical analysis indicated that all the study growth characters reached a maximum value under the Foliar NPK application (Figure 3). These values were gradually decreased under fertigation NPK applications. However, then the values rose slightly as the plants were treated with both Foliar and Fertigation NPK. Later on, the minimum values were recorded for all traits under control treatment. An increase in the number of leaves due to nitrogen fertilization usually increases leaf area, thus promoting a greater incidence of solar radiation, carbon assimilation, and plant growth (Cruz et al. 2007).

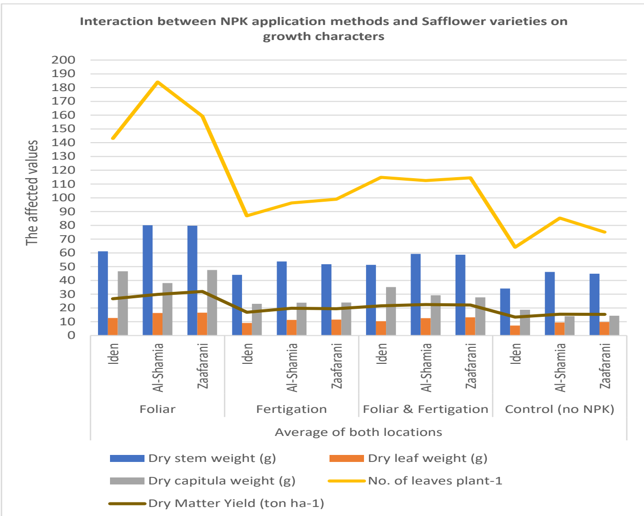



Figure 3. Effect of the interaction between NPK application and varieties on growth character at the average of both locations

The result displayed in (Appendix 1 and Figure 4) revealed that dry stem weight and dry matter yield were highly significantly different between the locations. However, the effect was significant for dry leaf weight and dry capitula weight and was not significant regarding the number of leaves plant$^{-1}$. The first location higher values for dry stem weight, dry leaf weight, dry capitula weight and dry matter yield by 55.14, 6.89, 8.68, and 38.68%, respectively, than the second location. These results indicated that the first location might be more suitable for the production of safflower.

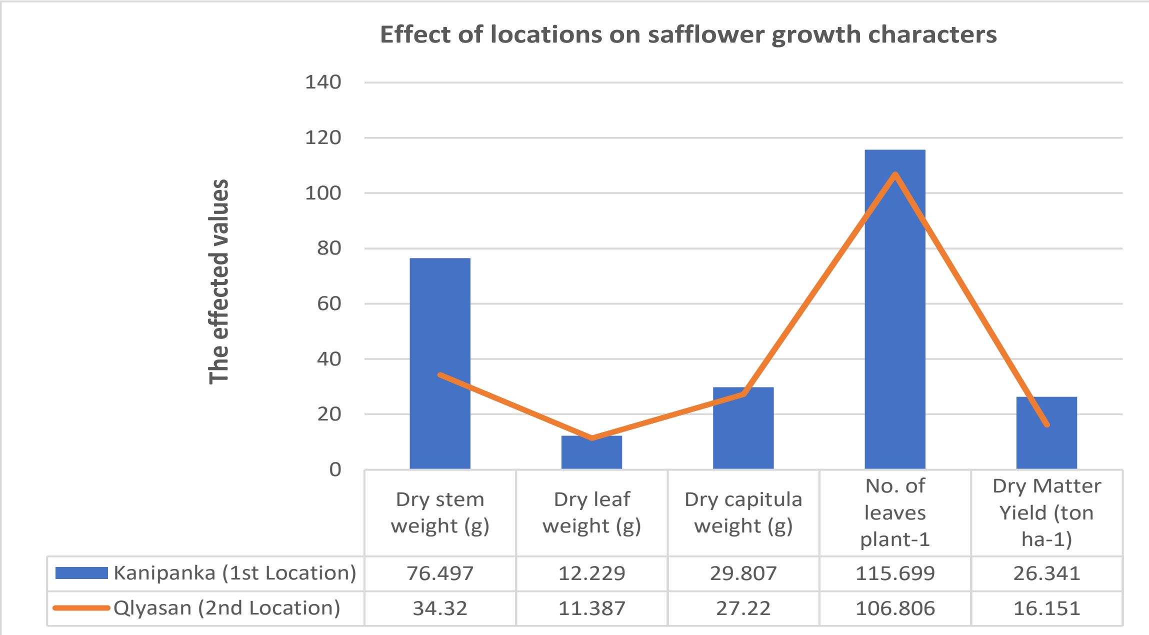



Figure 4. Effect of locations on safflower growth character

**Yield Components Traits** as shown in Appendix 2, NPK application methods highly significantly affected seed yield, and most of it is components at both locations and their average. However, the number of seeds plant$^{-1}$ was significant at the second location, and the harvest index was non-significant.

Foliar NPK application leads the rest of the other applications at the average of both locations for all traits. Seed yields from least to highest weight were 2.475-, 3.590-, 4.565-, and 7.185ton ha$^{-1}$ for Control, Fertigation, Foliar + Fertigation, and Foliar application, respectively. Different NPK application methods also influenced the other traits (Table 5.).

The Foliar NPK application methods' superiority followed by the Foliar + fertigation application for studied traits explained in the Principal Component Analysis. The relationships were counted for 99.92% of the total variations between various NPK applications and studied characters at the average of both locations. The biplot diagram indicated the highest foliar NPK application values for these components at the average of both locations (Figure 4.). Our study revealed that the number of capitula plant$^{-1}$ increased by foliar NPK application. Such an increase may be the leading cause of increasing all yield components, ultimately increase the seed yield. Wuhaib et al., (2017) confirm that the number of safflowers capitula directly affected seed yield. The exceeding of the Foliar NPK application on Fertigation, Foliar + Fertigation, and Control application for the number of capitula plant$^{-1}$ were 40.27%, 28.86%, and 53.62%, respectively, at the average of both locations. The results obtained from this study confirm those found by (Dorado and Sioulas, 2008; Abbadi and Gerendas, 2011; and Rastgou et al. 2013, who reported that increasing nitrogen fertilizer provide better results in increasing the number of safflowers capitula plant$^{-1}$ by 13% and 31%. Increasing phosphorus application to safflower plants increased seed yield and its components (Golzarfar et al. 2012; Singh and Singh, 2013; Malek and Ferri, 2014).

**Table (5) Effect of NPK application on seed yield and its components at the average of both locations**

| NPK application methods | No. of Capitula plant-1 | Capitula weight (g) | Seed weight (g) | No. of Seeds plant-1 | 1000 Seed weight (g) | Harvest index | Biological yield (ton ha-1) | Seed yield (ton ha-1) |
|---|---|---|---|---|---|---|---|---|
| Foliar | 34.556 a | 76.408 a | 32.332a | 708.109a | 45.666 a | 0.191 a | 36.729 a | 7.185 a |
| Fertigation | 20.639 c | 39.791 c | 16.154c | 437.571c | 36.829 c | 0.162 b | 22.284 c | 3.590 c |
| Foliar & Fertigation | 24.583 b | 51.229 b | 20.544b | 498.777b | 41.287 b | 0.169 b | 26.603 b | 4.565 b |
| Control (No NPK) | 16.028 d | 26.796 d | 11.140d | 362.932d | 30.453 d | 0.145 c | 17.182 d | 2.475 d |
| LSD 0.05 | 1.661 | 5.583 | 2.623 | 59.630 | 1.599 | 0.013 | 2.704 | 0.582 |

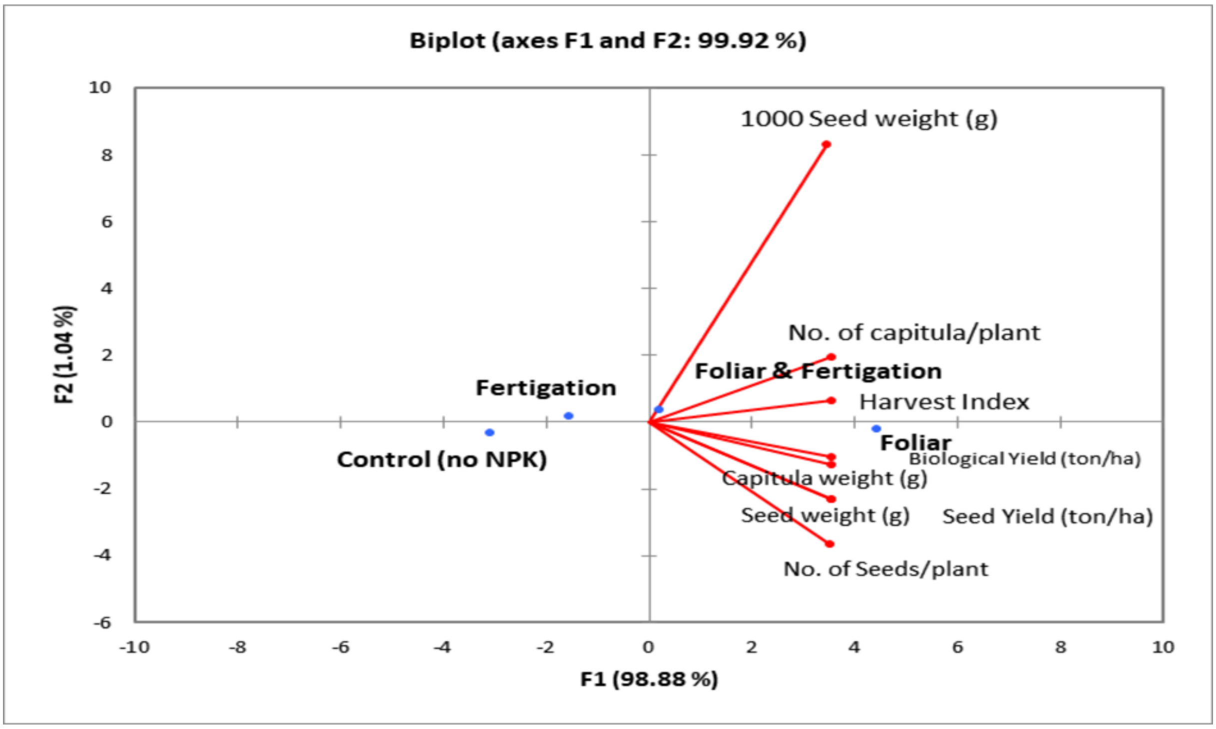



Figure 4. PCA plot showing the association between NPK application and seed yield and its components at the average of both locations

Combined data showed highly significant differences among all varieties for most studied characters at both locations and their average. However, the biological yield was significantly different at the first location only. No statistically significant differences were found in the number of seeds plant$^{-1}$ and the number of capitula plant$^{-1}$ at first, and the average of both locations (Appendix 2).

Regarding Principal Component Analysis, variable components accounted for 100% of the total variation for safflower varieties at the average of both locations. The biplot-PCA indicates the variation derived from the first and second factors for seed yield and its components. The highly significant weights of seed weight and 1000 seed weight, was due to the direct relation with the final seed yield. Zaafarani variety recorded the highest seed yield (Table 6 and Figure 5.). However, the Iden variety showed the highest capitula weight, the number of seeds plant$^{-1}$, and the harvest index. The results are consistent with results reported by (Osman and Ali, 2006; Çamaş et al. 2007; and Mokhtassi-Bidgoli et al. 2007), who showed that the yield and yield components of safflower were significantly affected by varieties.

**Table (6) Effect of safflower varieties on seed yield and its components at the average of both locations**

| Safflower varieties | No. of Capitula $plant^{-1}$ | Capitula weight (g) | Seed weight (g) | No. of Seeds $Plant^{-1}$ | 1000 Seed weight (g) | Harvest index | Biological yield (ton $ha^{-1}$) | Seed yield (ton $ha^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| Iden | 24.292 a | 51.184 a | 20.315 b | 530.485a | 36.808 b | 0.178 a | 24.149 b | 4.514 b |
| Al-Shamia | 24.333 a | 44.527 b | 18.240 c | 474.413c | 37.465 b | 0.151 b | 25.953 a | 4.053 c |
| Zaafarani | 23.229 a | 49.957 a | 21.572 a | 500.644b | 41.403 a | 0.171 a | 26.997 a | 4.794 a |
| LSD 0.05 | N. S | 2.123 | 0.806 | 26.152 | 0.964 | 0.009 | 1.418 | 0.179 |

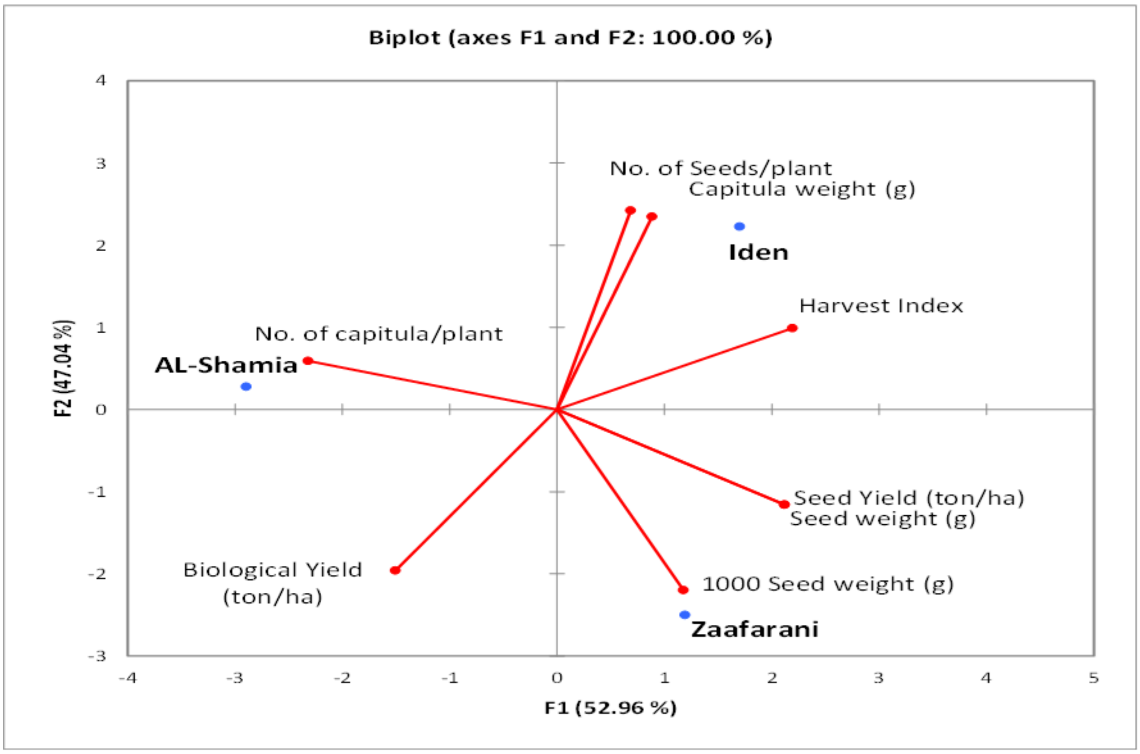



Figure 5. PCA plot showing the association between safflower varieties and seed yield and its components at the average of both locations

Seed yield components were affected by NPK application and varieties' interaction at each location and their average. As revealed at the first location, all characters responded significantly to the interaction effect except biological yield. At the second location, all the characters showed a significant response to this effect, except, number of seeds $plant^{-1}$. At the average of both locations, only the biological yield showed non-significant, while the rest recorded a highly significant effect (Appendix 2).

Figure 6 indicates the interaction between NPK application and varieties at the average of both locations. It also shows a different interaction between NPK applications and safflower varieties on yield and its components. The interaction between Foliar application and varieties reaches the maximum values. The highest value for seed weight, the number of seeds $plant^{-1}$, harvest index, and seed yield were recorded between Foliar application and Iden variety. However, the interaction between the Foliar NPK application and Zaafarani variety showed the maximum values for the number of capitula plant$^{-1}$, the capitula weight, and 1000 seed weight.

In contrast, the gradual dropped of values observed in the interaction between Fertigation applications and varieties. However, the values increased again by the interaction between Foliar + Fertigation application and varieties. Finally, the values of all interaction effects of Control plunged and hit bottom. The present study demonstrated that the Foliar NPK application significantly improved the yield and its components of safflower compared to the rest interaction. The increase in seed yield under the use of fertilizers can be attributed to the improved supply of photoassimilates resulting from the abundance of essential elements used to expand the sink cells (Dordas and Sioulas, 2008). This can be due to increased assimilated translocation from vegetative tissues to the achenes (Xie et al. 2014).

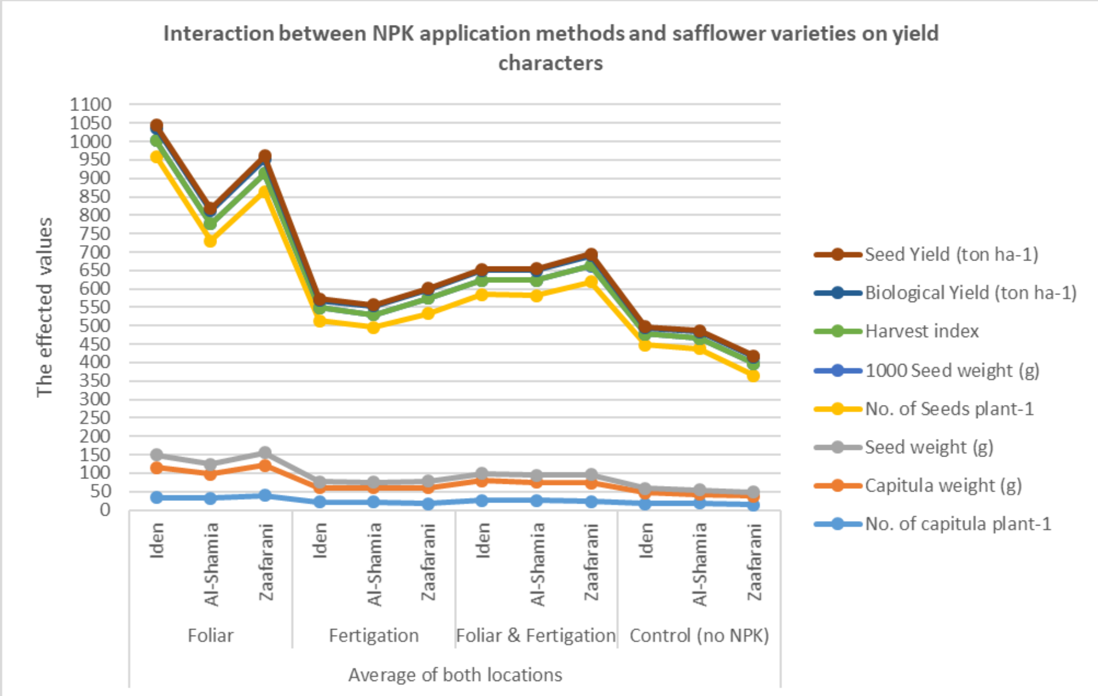
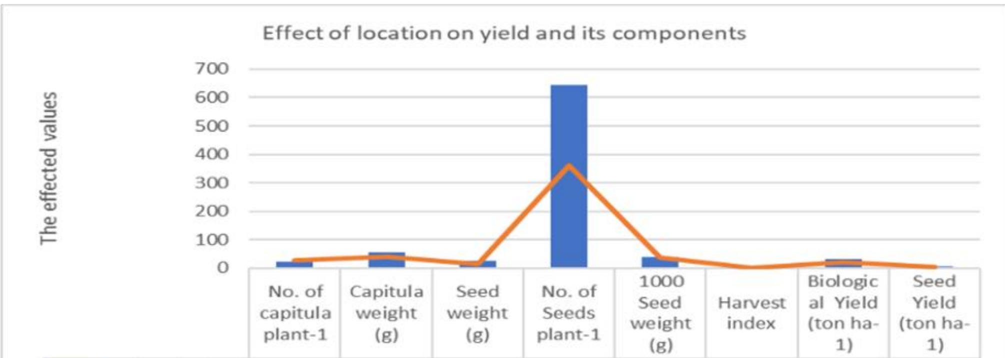



Figure 6. Effect of interaction between NPK application and safflower varieties on yield and its components at the average of both locations

Data in (Appendix 2 and Figure 7) showed the effect of locations on seed yield and its components. The results reveal the highest significant effect on all the traits. The statistical results confirmed that all studied characters showed the best value at the first location except the number of capitula plant$^{-1}$, which exhibited the best value at the second location and predominated the first location by 16.74%. The seed yield and its component at the first location exceeded values obtained from the second location due to higher capitula weight, seed weight, the number of seeds plant$^{-1}$,




| | No. of capitula plant-1 | Capitula weight (g) | Seed weight (g) | No. of Seeds plant-1 | 1000 Seed weight (g) | Harvest index | Biological Yield (ton ha-1) | Seed Yield (ton ha-1) |
|---|---|---|---|---|---|---|---|---|
| Kanipanka (1st) | 21.764 | 55.948 | 26.141 | 644.199 | 39.215 | 0.175 | 32.15 | 5.809 |
| Qlyasan (2nd) | 26.139 | 41.164 | 13.944 | 359.496 | 37.903 | 0.159 | 19.25 | 3.099 |

Figure 7. Effect of locations on safflower seed yield and it is components

1000 seed weight, harvest index, biological yield, and seed yield. The values were 26.42, 46.66, 44.2, 3.35, 9.14, 40.12 and 46.65% respectively. Higher seed yield may be due to different environmental conditions of each location. Productivity and quality are greatly influenced by genotype, environment, and interaction (Sidlauskas and Bernotas, 2003; Denčić et al. 2012).

**CONCLUSIONS**

The two locations from a semi-arid environment clearly showed that the safflower responded remarkably to recommended NPK fertilizers' applications. Fertigation-application is less effective, while the foliar application is more suitable in allowing nutrients to be absorbed directly by safflower plant parts. Foliar NPK application is an efficient way of avoiding nutrient deficiencies. Overall, the results showed that foliar NPK application significantly affected most of the growth and yield components. Foliar application increased seed yield by an average of 65.55%. The yield components such as the number of capitula plant$^{-1}$, capitula weight, seed weight, the number of seeds plant$^{-1,}$ and 1000 seed weight were increased in the study with foliar NPK application compared with the control. Safflower is well suited at the Kanipanka location for foliar fertilizer application, and the Zaafarani variety had a prominent effect on some growth, yield, and yield component.

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## تأثير أضافة السماد المركب NPK الورقي و دمج السماد في مياه الري على نمو ومكونات حاصل البذور للعصفر (*Carthamus tinctorius L.* )

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**الخلاصة**

يعد العصفر ( *Carthamus tinctorius L.* ) أحد المحاصيل الزيتية الحولية العائدة للعائلة النجمية Asteraceae. أجريت التجربة في موقعين مختلفين من اقليم كوردستان-العراق لدراسة تأثير طرق مختلفة من اضافة السماد المركب السائل NPK في النمو والحاصل ومكوناته لثلاث أصناف من العصفر. طبقت التجربة وفق تصميم القطاعات العشوائية الكاملة بنظام الالواح المنشقة وبثلاث مكررات. أذ كانت طرق اضافة السماد المركب التي تضمنت (التسميد الورقي و دمج السماد في مياه الري و التسميد الورقي + دمج السماد في مياه الري) وبدون تسميد تطبيقا للقطع الرئيسية. في حين مثلت الأصناف الثلاثة للعصفر(ايدن و الشامية و زعفرانية) القطع الثانوية. اعطى التسميد الورقي الحاصل الأعلى للمادة الجافة والبذور بـ 29.544 و 7.185 طن هـ-1 على التوالي كمعدل للموقعين. سجل صنف العصفر زعفرانية ذروة حاصلي المادة الجافة والبذور بـ 22.204 و 4.794 طن هـ-1 على التوالي كمعدل للموقعين. بين التحليل ألأحصائي لمعدل الموقعين تفوق اداء الصنفين ايدن و زعفرانية لصفة حاصل البذور ووصل الى 7.762 و 7.647 طن هـ-1 تحت ظروق التسميد الورقي لـ NPK بدون اختلاف معنوي بين هذين الصنفين. بالأستناد الى معدل الفعالية لأستخدام طرق التسميد والأصناف المختلفة على معظم مكونات النمو و الحاصل و مكوناته يكون الترتيب كالتالي: التسميد الورقي > التسميد الورقي + دمج السماد في مياه الري > دمج السماد في مياه الري> بدون تسميد(معاملة المقارنة) , بينما للأصناف كان الترتيب زعفرانية > ايدن > الشامية. دلت النتائج ان عدد الثمرات نبات-1 هي الصفة الاكثر تاثيرا في محصول بذور العصفر.

**الكلمات المفتاحية:**
المغذبات, طرق اضافة سماد NPK, حصل المادة الجافة, حاصل البذور, مواقع

## APPENDIX

(Appendix 1) Mean squares of variance analysis for growth character at both locations and their average

| S.O.V. | d.f | Dry stem weight (g) | Dry leaf weight (g) | Dry capitula weight (g) | No.of leaves plant$^{-1}$ | Dry Matter Yield (ton ha$^{-1}$) |
|---|---|---|---|---|---|---|
| First location | | | | | | |
| Block | 2 | 342.781 | 1.930 | 22.334 | 250.385 | 23.708 |
| NPK application | 3 | 3364.542** | 104.151** | 1663.67** | 19998.949** | 586.251** |
| E(a) | 6 | 186.429 | 2.187 | 57.391 | 341.19 | 17.973 |
| Varieties | 2 | 1552.754** | 57.185** | 155.505** | 609.018$^{N.S}$ | 69.063** |
| NPK * Varieties | 6 | 124.464$^{N.S}$ | 4.31* | 31.763* | 319.498$^{N.S}$ | 3.807$^{N.S}$ |
| E(b) | 16 | 140.213 | 1.572 | 9.941 | 230.668 | 10.691 |
| Second location | | | | | | |
| Block | 2 | 26.852 | 0.41 | 6.056 | 190.939 | 0.438 |
| NPK application | 3 | 582.473** | 39.644** | 1030.558** | 7097.154** | 192.938** |
| E(a) | 6 | 13.524 | 2.076 | 2.913 | 129.751 | 0.795 |
| Varieties | 2 | 64.262* | 11.9** | 228.074** | 1909.212** | 8.718** |
| NPK * Varieties | 6 | 12.151$^{N.S}$ | 1.756$^{N.S}$ | 160.393** | 475.297$^{N.S}$ | 5.19** |
| E(b) | 16 | 13.036 | 1.308 | 5.756 | 248.1 | 0.982 |
| Average of both locations | | | | | | |
| Location | 1 | 32019.808** | 21.405* | 120.484* | 1423.494$^{N.S}$ | 1869.001** |
| Block/L (Ea) | 4 | 184.816 | 1.17 | 14.195 | 220.662 | 12.073 |
| NPK application | 3 | 3307.122** | 133.506** | 2615.983** | 25321.954** | 712.618** |
| NPK * Location | 3 | 639.893 | 10.289 | 78.246 | 1774.149 | 66.571 |
| E(b)/L | 12 | 99.976 | 2.132 | 30.152 | 235.471 | 9.384 |
| Varieties | 2 | 1097.057** | 60.587** | 126.252** | 1800.713** | 47.304** |
| Varieties * Location | 2 | 519.96 | 8.499 | 257.326 | 717.517 | 30.478 |
| NPK * Varieties | 6 | 51.216$^{N.S}$ | 1.044$^{N.S}$ | 56.632** | 560.999$^{N.S}$ | 6.042$^{N.S}$ |
| NPK * Varieties * Location | 6 | 85.399 | 5.023 | 135.524 | 233.796 | 2.955 |
| E(c)/L | 32 | 76.624 | 1.44 | 7.848 | 239.384 | 5.836 |

(Appendix 2) Mean squares of variance analysis for yield and it is components at both locations and their average

| S.O.V. | d.f | No.of capitula plant$^{-1}$ | Capitula weight (g) | Seed weight (g) | No.of seeds plant$^{-1}$ | 1000 Seed weight (g) | Harvest index | Biological Yield (ton ha$^{-1}$) | Seed Yield (ton ha$^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|
| First location | | | | | | | | | |
| Block | 2 | 7.111 | 52.251 | 15.736 | 9445.743 | 1.335 | 7.3E-05 | 32.967 | 0.777 |
| NPK application | 3 | 386.248** | 6524.2** | 1603.82** | 495541.348** | 298.166** | 0.007** | 1095.802** | 79.201** |
| E(a) | 6 | 2.185 | 109.005 | 21.826 | 9372.903 | 2.975 | 0.0002 | 26.681 | 1.078 |
| Varieties | 2 | 49.299** | 124.084** | 21.614** | 5578.908$^{N.S}$ | 81.023** | 0.002** | 64.57* | 1.067** |
| NPK * Varieties | 6 | 13.428* | 93.987** | 37.652** | 27800.492** | 4.552** | 0.001* | 2.337$^{N.S}$ | 1.859** |
| E(b) | 16 | 4.188 | 15.71 | 2.488 | 2935.058 | 1.653 | 0.0003 | 10.42 | 0.123 |
| Second location | | | | | | | | | |
| Block | 2 | 1.882 | 6.469 | 0.774 | 608.768 | 1.527 | 9.04E-05 | 0.722 | 0.038 |
| NPK application | 3 | 765.787** | 2194.986** | 219.769** | 39423.737* | 477.457** | 0.001$^{N.S}$ | 294.865** | 10.853** |
| E(a) | 6 | 8.280 | 9.15 | 4.253 | 4106.868 | 6.727 | 0.0004 | 1.032 | 0.21 |
| Varieties | 2 | 29.299** | 486.876** | 49.082** | 23530.983** | 75.465** | 0.003** | 18.372** | 2.424** |
| NPK * Varieties | 6 | 62.141** | 199.167** | 5.671** | 1630.868$^{N.S}$ | 10.554* | 0.0006* | 6.133** | 0.28** |
| E(b) | 16 | 4.347 | 10.24 | 1.255 | 1001.349 | 3.696 | 0.0002 | 1.16 | 0.062 |
| The average of both locations | | | | | | | | | |
| Location | 1 | 344.531** | 3934.362** | 2677.851** | 1459003.611** | 31.008** | 0.005** | 2995.535** | 132.239** |
| Block/L (Ea) | 4 | 4.497 | 29.36 | 8.255 | 5027.255 | 1.431 | 8.17E-05 | 16.845 | 0.408 |
| NPK application | 3 | 1119.624** | 7999.228** | 1473.983** | 395893.265** | 759.938** | 0.006** | 1240.139** | 72.789** |
| NPK * Location | 3 | 32.411 | 719.959 | 349.607 | 139071.82 | 15.686 | 0.002 | 150.528 | 17.264 |
| E(b)/L | 12 | 5.233 | 59.078 | 13.039 | 6739.886 | 4.851 | 0.0003 | 13.856 | 0.644 |
| Varieties | 2 | 9.399$^{N.S}$ | 301.183** | 67.916** | 18890.542** | 148.214** | 0.005** | 49.846** | 3.354** |
| Varieties * Location | 2 | 69.198 | 309.777 | 2.78 | 10219.348 | 8.274 | 0.0002 | 33.096 | 0.137 |
| NPK * Varieties | 6 | 60.27** | 116.944** | 29.286** | 19162.42** | 10.66** | 0.001** | 6.151$^{N.S}$ | 1.446** |
| NPK * Varieties * Location | 6 | 15.3 | 176.21 | 14.037 | 10268.94 | 4.445 | 0.0004 | 2.319 | 0.693 |
| E(c)/L | 32 | 4.267 | 12.975 | 1.872 | 1968.204 | 2.675 | 0.0002 | 5.79 | 0.092 |