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Passer Journal of Basic and Applied Sciences

Passer

Passer 7 (Issue 1) (2025) 245-256

Original Article

Impact of Microelement Treatments on Nutrient Uptake in Two Wheat Varieties at Different Growth Stages

Dilan Rizgar Hadi[1], Bahar Jalal Mahmood*[1], Tareeq Hama Kreem[2]

[1]*Department of Field crops medical plants, Collage of Agricultural Engineering Sciences, Salahaddin University- Erbil, Iraq.*
[2]*Department of Surveying and Geomatics Engineering, Faculty of Engineering, Tishk International University, Erbil, Iraq.*

Received 7 December 2024; revised 24 January 2025;
accepted 03 March 2025; available online 25 May 2025

DOI: 10.24271/PSR.2025.492470.1848

ABSTRACT

An experiment was conducted at Grdarasha Agriculture Research Station of Agricultural Engineering Sciences College / Salahaddin University- Erbil, to investigate the uptake of certain micro nutrients in wheat. A factorial experiment of (2 x 4 x 2) was carried out using a Randomized Complete Block Design (RCBD) using three replications. The study involved two wheat varieties (Hawler 2 and Hawler 4), and four micronutrient treatments F_1 = control, F_2 = Iron (Fe) applied at 5 kg Fe ha^{-1} in the form of $FeSO_4.7H_2O$, F_3 = Zinc applied at 5 kg Zn ha^{-1} in the form of $ZnSO_4.7H_2O$ and F_4 = Combination of Fe and Zn (5 kg Fe + 5 Kg Zn ha^{-1}). The treatments were applied at two growth stages tillering (GS Z25) and booting (GS Z45). The results showed that Hawler 2 variety exhibited a significantly respond to the uptake of most elements. There were no significant differences in nutrients uptake for the growth stages except iron and phosphorous in grains which increased at the tillering stages and phosphor in the, which increased at the botting stages. Zinc Applying enhanced of most elements in both straw and grains excluding potassium and iron in the grains which increased due to of iron application, while the combination of iron and zinc significantly increased the uptake of nitrogen and phosphorus in the wheat grain.

Keywords: Wheat varieties, Microelement uptake, Fertilization treatments, Growth stages.

1 Introduction

Wheat (*Triticum aestivum* L.) considered one of the most important cereal crops of the world and is a staple food for about one third of the world's population [1] It is the most extensively grown of all the cereals and has an essential role among them since it is used for food, animal feed, and as a raw material for several commercial products [2].

Kurdistan soils are generally slightly alkaline and calcareous. The soil calcium carbonate in agricultural land in Kurdistan region is ranged between 10 to 30%, which causes the decrease in availability of micro nutrients, for this reason, fertilization is a method for solving this problem and improving crop yield and quality. micronutrients reduced in soil day by day because of more requirements on artificial fertilizers and inclining in cropping intensity with high yielding, which causes an imbalance of nutrients for this reason adding Fe and Zn fertilizers are necessary [3]

* Corresponding author
E-mail address bahar.mahmmod@su.edu.krd (Instructor).
Peer-reviewed under the responsibility of the University of Garmian.

Nowadays more than 45% of people suffer from micronutrient deficiency, which causes many health problems, overstated economic costs accepted by society, and learning disabilities for children [4]. Better crop production and improved human health is an important global challenges due to increasing zinc and iron concentrations in food crop plants [5].

It was recognized that micronutrients have an important role in yield improvement [6]. It is realized that the application of micronutrient fertilizers caused a significant increase in total uptake of some micronutrients such as Zn, Cu, Fe and Mn, in grain and flag leaves [7].

[8] concluded that iron is an important nutrient for the respiration and photosynthesis processes. While, Arif [9] reported that foliar application of micronutrients (Fe) causes the increase in the concentration of micronutrient in wheat grain this influence may be qualified essentially to the important physiological roles in the plant cells. Zinc is a vital element existing in plant enzymatic systems. It was stated that zinc has a huge role in plant metabolism [10].

The aim of this study is to evaluate the effects of microelement treatments (iron, zinc, and their combination) on the uptake of essential nutrients in two wheat varieties (Hawler 2 and Hawler 4) at different growth stages (tillering and booting).

2 Materials and Methods

2.1 Study location

A field experiment was carried out at the Grdarasha Agriculture Research Station belongs to the Field Crops and Medicinal Plants Department of Agricultural Engineering Sciences College at Salahaddin University – Erbil, Kurdistan region with a GPS reading of (36.10116° N, 44.00925° E), at an elevation of 415 meters above sea level.

2.2 Experimental Design

The study was designed as a Randomized Complete Block (RCBD) using three replicates to study the influence, of some micronutrient foliar applications on Fe, Zn, N, P and K uptake during two growth stages of two wheat varieties (*Triticum aestivum* L.). The land was separated into three blocks each one consisting of 16 plots, on 4th November, the grains were sown manually at the rate of 100 kg ha^{-1} on a silty clay loam soil with 0.91% organic matter, 89.17 ppm available nitrogen, 5.36 ppm available P and 64.10 ppm potassium Table 1. Metrological data were taken from Meteorological Directory- Erbil province during the growing season as shown in Table 2.

Table 1: Some Chemo-Physical Properties of the Experiment Soil at Gardarah site. [11].

Soil properties		Units	Grdarasha
Particle Size distribution	Sand	(g kg^{-1})	384.75
	Silt		515.00
	Clay		100.25
Soil texture			Silty clay loam
Soil pH			7.53
ECe		dS m^{-1}	0.38
Organic matter content		(g kg^{-1} soil)	9.1
Calcium carbonate			269.10
Available nitrogen		(mg kg^{-1}soil)	59.67
Available Phosphorous			2.01
Available potassium			64.10

*Laboratory Soil and Water Sciences Department, College of the Agricultural Engineering Sciences, University of Duhok.

The samples were taken from the treatment combination of three factors, the first factor contains two soft wheat varieties V_1= Hawler 2 and V_2 = Hawler 4 were imported from Agriculture Research Center- Erbil. The second factor included F_1= Control, F_2 = Iron (Fe) at a rate of 5 kg Fe ha^{-1} in form of $FeSO_4.7H_2O$ with a concentration of 0.67 g Fe L^{-1}, F_3= Zinc (Zn) at a rate of 5 kg Zn ha^{-1} in form of $ZnSO_4.7H_2O$ with a concentration of 0.67 g Zn L^{-1}, and F_4= Combination of Fe and Zn (5 kg Fe + 5 Kg) Zn ha^{-1}. The third factor included two growth stages S_1 = tillering and S_2 = booting stages. Besides micronutrients, every treatment had received the same recommended dose of NPK. Table 1 presents some selected some chemical and physical properties of the soil at the experimental site.

2.3 Studied Characters

Grain and straw samples were selected randomly from the treatment combinations of micro nutrient application during two growth stages of the two wheat varieties.

1.The uptake of some macro elements in grain and straw which included: Nitrogen, Phosphorus and Potassium kg ha^{-1}.2. The uptake of some micro elements in grain and straw which included: Uptake by straw (dry matter) of iron, zinc was attained by the elements content in the straw (stem and leaf) multiplied by straw yield [12].

The elements uptake by grain or straw = concentration of nutrient * dry weight.

Table 2: Climatic conditions during the growing season**.**

Months	Air Temp. C°		Relative moisture %	Rainfall (mm)
	Minimum	Maximum		
September	26.1	38.4	16.0	0.7
October	20.0	30.0	30.7	10.1
November	13.4	21.5	60.5	46.5
December	9.5	18	67.0	66
January	7.9	14.8	72.1	142
February	7.8	15.9	62.5	71
March	11	19.5	52.5	67
April	18.3	29.2	34.3	46
May	20.6	30.7	32.7	
June	29.8	41	12.9	

*Data source: Meteorological Directory- Erbil province.

2.4 Statistical analysis

The data were statistically analyzed according to the technique of analysis of variance (ANOVA) for randomized complete block design (RCBD) using SPSS program version (26), the difference among means of treatments were tested using Duncan's multiple range test [13].

Cluster analysis was conducted between the uptake of nutrients in grouping them into different classes using XLSTATE-premium program (2016) to obtain homogenous groups by Agglomerative Hierarchical Clustering (AHC) and Principal Component Analysis (PCA) to show the similarity between the treatment combination.

3 Results and Discussion

3.1 Iron uptake in straw and grain (g ha^{-1})

Iron uptake in straw of wheat varieties exhibited significant responses to micronutrient foliar application treatments as shown in Table 3. The maximum amount (194.42) g ha^{-1} was recorded from (V_1), while the least amount (149.22) g ha^{-1} was recorded by (V_2), additionally according to iron uptake, the highest mean value (235.56) g ha^{-1}was obtained from (F_3) treatment while the lowest Fe uptake (105.37) g ha^{-1} was recorded from (F_1).

The two treatments combination was found to be significant, maximum iron uptake between ($V_1 \times S_2$), ($V_1 \times F_3$) and (F_3 x S_2) were recorded with values (204.35), (290.93) and (252.62) g ha^{-1} respectively. Whereas the treatment combinations ($V_1 \times F_1$) and ($V_2 \times S_1$) and (F_1* S_1) were achieved the lowest mean values (103.54), (140.94) and (105.03) g ha^{-1} respectively.

The combinations between the treatments had a positive effect on iron uptake. The highest value (312.62) g ha^{-1} was noted from the treatment combination ($V_1 \times F_3 \times S_2$) which is equivalent to (1.56 kg iron fertilizer ha $^{-1}$) while the lowest Fe uptake (101.35) g ha^{-1} was achieved from the treatment combination ($V_1 \times F_1 \times S_1$) which equivalent to (0.50 kg iron fertilizer ha $^{-1}$.

Table 3. Shows that Zinc led to an increase in iron uptake in straw this was in harmony with [14], they revealed that Zn increased Zn and NPK uptake by wheat crop, over control treatments. A positive correlation between grain Zn and Fe concentrations in cereals has been reported by many studies [15 and 16]. The treatment combination V * F shows the highest value in (V_1* F_2) this may be due to the genetic variation of variety to accumulate Fe and the effect of fertilizer applied as well as the favorable environmental conditions that let the plant to absorb Fe and Zn [12].

Iron uptake in grains achieved significant responses to micronutrient foliar application at two stages as shown in Table 4. The highest Fe uptakes (242.02 and 200.02) g ha^{-1} were recorded from (F_2) and (S_1) respectively, while the lowest mean values (143.12 and 181.35) g ha^{-1} were produced from the treatments (F_1) and (S_2) respectively. In addition, it was noticed that the treatment combination ($V_1 \times F_2$) was significant and received the highest Fe uptake (263.23) g ha^{-1} whereas, the treatment combination ($V_1 \times F_1$) obtained the lowest value (117.17) g ha^{-1}, these results indicated that varieties had no significant effect on this trait as shown from statistical analysis. Regarding, the significant effect of treatment combinations between the fertilizers * growth stages it was shown that the maximum amount (260.62) g ha^{-1} obtained from ($F_2 \times S_1$), but smallest value (133.14) g ha^{-1} noted from the treatment combinations ($F_1 \times S_1$).

The treatment combinations between the three studied features showed the smallest effect on the same trait. The maximum and minimum values (305.61 and 104.07) g ha^{-1} were received from the treatment combinations ($V_1 \times F_2 \times S_1$) and ($V_1 \times F_1 \times S_1$) respectively. Table 4. Indicated an increase in iron uptake in wheat grain with an increase in levels of applied Fe, this may be due to the essential physiological characteristics of iron in plant cells [9]. These outcomes were consistent with those found by [17], they specified that generally spraying of Fe Increases Fe uptake of wheat grain (Table 1) shows high calcium carbonate (31.20%) soil which caused decrease availability of nutrients due to chemical and physical fixation, as mentioned by [18].

Table 3: Combination effect among micronutrient foliar application and growth stages on iron uptake (g Fe ha^{-1}) in straw.

Variety	Stages	F_1	F_2	F_3	F_4	Varieties	Stages
V_1	S_1	101.35^{f}	237.51^{bcd}	269.24^{ab}	146.30^{ef}	194.42^{a}	S_1 = 162.71^{a}
	S_2	105.72^{f}	249.83^{abc}	312.62^{a}	176.95^{def}		
V_2	S_1	107.61^{f}	142.14^{ef}	172.36^{def}	130.20^{ef}	149.22^{b}	S_2 = 180.93^{a}
	S_2	106.08^{f}	176.90^{def}	198.92^{cde}	142.27^{ef}		
Fertilizer means		105.37^{d}	201.84^{b}	235.56^{a}	150.24^{c}		
V x S		184.48^{ab}	204.35^{a}	140.94^{b}	157.50^{b}		
V_1 x F		103.54^{e}	243.67^{b}	290.93^{a}	161.63^{cd}		
V_2 x F		106.85^{e}	159.52^{cd}	185.64^{c}	136.24^{de}		
S_1 x F		105.03^{d}	188.70^{abc}	218.50^{a}	139.61^{cd}		
S_2 x F		105.71^{d}	214.98^{ab}	252.62^{a}	160.86^{bcd}		

*Mean values followed by the same letter are not significantly different at the 5% probability level.

Table 4: Combination effect among micronutrient foliar application and growth stages on iron uptake (g Fe ha^{-1}) in grains.

Variety	Stages	F_1	F_2	F_3	F_4	Varieties	Stages
V_1	S_1	104.07^{h}	305.61^{a}	167.54^{fg}	270.30^{ab}	193.25^{a}	S_1 = 200.02^{a}
	S_2	130.26^{gh}	220.85^{cde}	161.28^{fg}	207.12^{bcd}		
V_2	S_1	165.00^{fg}	214.32^{cde}	156.00^{fg}	235.01^{bc}	188.12^{a}	S_2 = 181.35^{b}
	S_2	176.96^{ef}	221.62^{cd}	146.94^{fgh}	188.31^{def}		
Fertilizer means		143.12^{b}	242.02^{a}	159.13^{b}	226.19^{a}		
V x S		207.81^{a}	178.69^{a}	192.22^{a}	184.01^{a}		
V_1x F		117.17^{e}	263.23^{a}	164.41^{d}	238.71^{ab}		
V_2 x F		170.98^{d}	217.91^{bc}	151.47^{de}	211.66^{c}		
S_1 x F		133.14^{c}	260.62^{a}	163.36^{c}	253.04^{a}		
S_2 x F		153.09^{c}	223.41^{ab}	154.90^{c}	199.33^{d}		

*Mean values followed by the same letter are not significantly different at the 5% probability level. 1g Fe = 4.98g iron fertilizer ($FeSO_4.7H_2O$).

3.2 Zinc uptake in straw and grain (g ha^{-1})

Tables 5 and 6 show significant differences between only the fertilizers on Zn uptake by straw and grains. The treatments (F_3 and F_3) recorded the highest Zn uptake (55.61 and 31.03) g ha^{-1} while and F_4 and F_1 (25.23 and 19.69) recorded the lowest value for straw and grains respectively. The treatment combination between (varieties and fertilizers) had a significant influence on the same trait. The highest mean value (59.03 and 34.60) g ha^{-1}

was received from the treatment combination ($V_2 \times F_3$) and ($V_1 \times F_3$) for straw and grain. Whereas the lowest Zn uptake (22.83 and 15.75) g ha^{-1} was obtained from ($V_2 \times F_4$) and ($V_1 \times F_1$) respectively. On the other hand, a significant effect of treatment combination ($F_3 \times S_2$) was noted for both straw and grain, with the highest mean value (65.18 and 31.22) g ha^{-1}, while ($F_4 \times S_1$) and ($F_1 \times S_1$) recorded the lowest Zn uptake with values (23.49 and 18.34) g ha^{-1} as shown in both table 5 and 6.

The treatment combination among the three studied factors significantly influences on Zn uptake by wheat straw Table 5. The highest Zn uptake (58.12) g ha^{-1} was recorded from ($V_2 \times F_3 \times S_2$) which is equal to (0.31 kg Zn fertilizer ha^{-1}) whereas, the lowest mean value (20.46) g ha^{-1} was received from ($V_2 \times F_4 \times S_1$) which equivalent to 0.09 kg $ZnSO_4$. fertilizer per hector used as a foliar application. Shaheen [19] studied the effect of zinc on Zn uptake by wheat straw, they concluded that the uptake of Zn was increased significantly with the application of zinc as shown in Table 5. This result supports the previous findings of [20], who found that Zn foliar application resulted in an increase in Zn concentration by 99%.

The treatment combination (V_2 x F_4) shows the lowest uptake of Zn, this may be due to the difference in the ability of the variety and the negative effect of Fe fertilizer on Zn concentration. Furthermore (S_2 x F_3) recorded the highest value, this may be due to favorable conditions at the booting stage as well as the positive effect of the application of Zn alone than the combinations form.

Table 5: Combination effect among micronutrient foliar application and growth stages on uptake (g ha^{-1}) in straw.

Variety	Stages	F_1	F_2	F_3	F_4	Varieties	Stages
V_1	S_1	27.90 ^{c}	23.09 ^{c}	43.34^{bc}	26.50 ^{c}	31.07 ^{a}	S_1 = 31.37 ^{a}
	S_2	22.06 ^{c}	29.17 ^{c}	52.92 ^{b}	27.80 ^{c}		
V_2	S_1	41.06^{bc}	26.37 ^{c}	46.19^{bc}	20.46 ^{c}	34.04 ^{a}	S_2 = 33.74 ^{a}
	S_2	29.92^{bc}	22.36 ^{c}	58.12 ^{a}	25.19 ^{c}		
Fertilizer means		30.45 ^{b}	26.40 ^{b}	55.61 ^{a}	25.23^{b}		
V x S		29.93 ^{a}	32.20 ^{a}	32.81 ^{a}	35.27^{a}		
V_1 x F		24.98 ^{c}	26.13 ^{c}	48.13 ^{ab}	27.15 ^{c}		
V_2 x F		35.49^{bc}	24.37 ^{c}	59.03 ^{a}	22.83 ^{c}		
S_1 x F		34.98^{bc}	26.61 ^{c}	46.04 ^{b}	23.49 ^{c}		
S_2 x F		25.92^{c}	26.18 ^{c}	65.18 ^{a}	26.96 ^{c}		

*Mean values followed by the same letter are not significantly different at the 5% probability level.

Table 6: Combination effect among micronutrient foliar application and growth stages on zinc uptake (g ha^{-1}) in grains.

Variety	Stages	F_1	F_2	F_3	F_4	Varieties	Stages
V_1	S_1	14.87 ^{h}	29.09^{b-e}	33.35^{abc}	30.50 $^{a-d}$	26.85 ^{a}	S_1= 27.12 ^{a}
	S_2	16.63^{gh}	24.25^{def}	35.84^{ab}	32.89 ^{a}		
V_2	S_1	21.98^{efg}	28.32^{c-f}	28.08^{c-f}	30.39 $^{a-d}$	25.86 ^{a}	S_2 = 25.58 ^{a}
	S_2	25.76^{c-f}	22.57^{efg}	26.88^{c-f}	21.00^{fgh}		
Fertilizer means		19.69 ^{c}	26.16 ^{b}	31.03 ^{a}	28.65 ^{a}		
V x S		26.68 ^{a}	27.01 ^{a}	27.56 ^{a}	24.15 ^{a}		
V_1 x F		15.75 ^{c}	26.67 ^{b}	34.60 ^{a}	31.70 ^{a}		
V_2 x F		23.87 ^{b}	25.45 ^{b}	27.48 ^{b}	25.85 ^{b}		
S_1 x F		18.34 ^{c}	28.75^{ab}	30.83^{ab}	30.63^{ab}		
S_2 x F		21.04 ^{c}	23.56^{bc}	31.22 ^{a}	26.67 ^{ab}		

*Mean values followed by the same letter are not significantly different at the 5% probability level.

Table 6 illustrates that Zn uptake by wheat grain from the treatment combination ($V_1 \times F_4 \times S_2$) recorded the highest mean value (32.89) g ha^{-1} while ($V_1 \times F_1 \times S_1$) achieved the lowest Zn uptake (14.87) g ha^{-1}. The same table depict significantly the effect of Zn application on its uptake in wheat grains, this was in agreement with the findings of [17], [21] and [22] they stated that a substantial increase in Zn concentration in wheat grains was due to singular application of Zn. It was concluded that foliar application of Zn micronutrient, caused good performance in maximizing their concentration in wheat grain [23]. Iron Sulphate alone or in combination with zinc Sulphate was the most effective in correcting graining chlorosis (90%) when grown on calcareous soils [24 and 25]. Etienne [22] unveiled that Zinc applied alone improved the Zn concentration of whole grain as shown in Table 6 and the highest uptake in the treatment combination (F_3* S_2) and (V_1* F_3) recorded the highest value, this may be due to difference in the ability of variety in Zn accumulation and favorable condition in the booting stage for Zn uptake.

Table 7: Combination effect among micronutrient foliar application and growth stages on nitrogen uptake (kg ha^{-1}) in straw.

Variety	Stages	F_1	F_2	F_3	F_4	Varieties	Stages
V_1	S_1	41.28^{de}	67.53^{ab}	79.72^{a}	56.22^{bcd}	59.86^{a}	$S_1 = 49.70^{a}$
	S_2	37.68^{de}	66.57^{abc}	80.53^{a}	53.52^{b-e}		
V_2	S_1	36.96^{de}	36.17^{de}	48.63^{b-e}	31.61^{e}	43.05^{b}	$S_2 = 53.21^{a}$
	S_2	35.06^{de}	43.47^{de}	68.39^{ab}	44.45^{cde}		
Fertilizer means		37.72^{c}	52.91^{b}	69.21^{a}	46.22^{bc}		
V x S		60.81^{a}	58.91^{a}	38.59^{b}	53.21^{a}		
V_1 x F		39.48^{cd}	67.05^{b}	80.12^{a}	54.87^{bc}		
V_2 x F		36.01^{d}	39.82^{cd}	58.51^{b}	38.03^{cd}		
S_1 x F		39.13^{c}	50.86^{bc}	63.28^{ab}	42.95^{c}		
S_2 x F		36.31^{c}	54.96^{bc}	75.14^{a}	49.50^{bc}		

*Mean values followed by the same letter are not significantly different at the 5% probability level.

Table 8: Combination effect among micronutrient foliar application and growth stages on nitrogen uptake (kg ha^{-1}) in grains.

Variety	Stages		F_1	F_2	F_3	F_4	Varieties	Stages
V_1	S_1		29.84^{f}	34.57^{def}	48.29^{bc}	63.63^{a}	44.23^{a}	$S_1 = 40.24^{a}$
	S_2		39.22^{c-f}	50.38^{b}	44.46^{bcd}	44.95^{bc}		
V_2	S_1		40.09^{b-f}	32.24^{ef}	32.77^{ef}	42.54^{b-e}	34.07 b	S_2 = 38.06 a
	S_2		35.13^{def}	13.32^{g}	41.18^{b-e}	34.09^{def}		
Fertilizer means			36.33^{c}	32.01^{c}	41.63^{b}	46.09^{a}		
V x S			43.48^{ab}	44.99^{a}	37.00^{bc}	31.14^{c}		
V_1 x F			34.53^{c}	42.48^{bc}	46.38^{b}	54.29^{a}		
V_2 x F			37.61^{bc}	22.78^{d}	36.98^{bc}	38.31^{bc}		
S_1 x F			35.08^{b}	33.48^{b}	40.18^{b}	52.71^{a}		
S_2 x F			37.58^{b}	30.54^{b}	43.08^{ab}	39.47^{ab}		

*Mean values followed by the same letter are not significantly different at the 5% probability level.

3.3 Nitrogen uptake in straw and grain (kg ha^{-1})

Table 7 explains hat N uptake by wheat straw was significantly affected by the two individual factors, varieties and fertilizers. The highest values (59.86 and 69.21) kg ha^{-1} were received from (V_1 and F_3) treatments respectively, while the lowest nitrogen uptakes (43.05 and 37.72) kg ha^{-1} were received by (V_2 and F_1). A significant effect of treatment combination presented in the same table ($V_1 \times F_3$) which recorded the highest value (80.12) kg ha^{-1}, while the smallest amount (36.01) kg ha^{-1} was obtained at ($V_2 \times F_1$).

The varieties and fertilizers with growth stages had significant influence on N uptake. The highest mean value (60.81 and 75.14) kg ha^{-1} was received by the treatment combination ($V_1 \times S_1$) as well as ($F_3 \times S_2$) whereas, the minimum N uptake (38.59 and 36.31) kg ha^{-1} was obtained from the ($V_2 \times S_1$) and ($F_1 \times S_2$) respectively.

The results in Table 7 were in agreement with the finding of [26] which stated that the foliar application with Zn remained comparatively the best regarding straw nitrogen uptake. Regarding the effect of the three studied factors on wheat straw, significant effects were observed. T the highest N uptake (80.53) kg ha^{-1} was recorded by the combination ($V_1 \times F_3 \times S_2$) however, the lowest Nitrogen uptake (31.61) kg ha^{-1} was achieved at ($V_2 \times F_4 \times S_1$).

The data from Table 8 illustrated a significant difference between the varieties in N uptake by wheat grain. The treatment (V_1) increases N uptake by 29.82% compared with (V_2). Regarding, the effect of fertilizers application on the same trait it showed significant effect, the (F_4) obtained the highest N uptake (46.09) kg ha^{-1} however, the application of (F_2) alone received the lowest mean value (32.01) kg ha^{-1} even less than (F_1).

In addition, the treatment combinations between varieties and each of the growth stages and fertilizers. The highest values (44.99 and 54.29) kg ha^{-1}were received from the treatment combinations ($V_1 \times S_2$) and ($V_1 \times F_4$) respectively. Furthermore, N uptake was significantly affected by the treatment combinations of fertilizers and growth stages, the application of (F_4) at (S_1) recorded the highest mean value (52.71) kg ha^{-1} whereas, spraying (F_2) alone at the (S_2) obtained the lowest N uptake (30.54) kg ha^{-1}. Finally, the combinations among varieties, fertilizers and growth stages had a positive significant effect on the N uptake by grain, the treatment combinations ($V_1 \times F_4 \times S_1$) achieved the highest mean value of (63.62) kg ha^{-1} while, ($V_2 \times F_2 \times S_2$) recorded the lowest N uptake of (13.32) kg ha^{-1}.

The application of (F_2) alone in Table 8 received the lowest mean value even less than control which may be due to the negative effect of (F_2) fertilizer alone on the N uptake by grain or may be due to the synergetic effect of Fe nitrate between Fe and $N\text{-}NH_4^+$ Among treatments, the increase in N uptake in wheat grain as illustrated in Table 8 and mentioned by [27] in (S_2 x F_2), was due to the application of Fe nutrient shared with other micronutrients at different growth stages.

3.4 Phosphorus uptake in straw and grain (kg ha^{-1})

Data presented in Tables 9 and 10 depict that there is a significant variation among varieties on phosphorous uptake by wheat straw and grain, in which V_1 recorded the best result (3.49 and 8.22) kg ha^{-1} respectively, as well as there was a significant influence of fertilizers on the same trait. The highest P uptake (3.83 and 8.80) kg ha^{-1} was achieved from the application of (F_3 and F_4) while, the lowest mean value (2.31 and 6.77) kg ha^{-1} from (F_4 and F_2) on straw and grain respectively. Although, growth stages showed significant differences on the same trait, the highest uptakes (3.29 and 7.78) kg ha^{-1} were obtained from (S_2 and S_1) for straw and grain respectively.

The best treatment combination which produced the largest amount of Phosphorus uptake in straw as shown in Table 9 was from ($V_1 \times S_2$) with a value (3.65) kg $ha^{-1,}$ however ($V_2 \times S_1$) recorded the lowest mean value (2.16) g ha^{-1} kg ha^{-1}. A significant effect was obtained from the combination between varieties and fertilizers on the uptake of P in straw. The highest mean value (4.15) kg ha^{-1} was received from the treatment combinations ($V_1 \times F_3$) while, the lowest P uptake (1.88) kg ha^{-1} was received by ($V_2 \times F_2$). The effect of treatment combination among fertilizers as well as growth stages showed significant differences, the application of (F_3) fertilizers at (S_2) made the plants receive the highest mean value (4.45) kg ha^{-1} whereas, spraying of combined fertilizers (F_4) at the same growth stage (S_2) recorded the lowest P uptake by straw (2.31) kg ha^{-1}.It was also evident from the presented data shown in Table 9 that the treatment combinations between the studied factors showed significant differences. The highest P uptake (4.57) kg ha^{-1} was recorded from ($V_1 \times F_3 \times S_2$) however, the lowest mean value (1.73) kg ha^{-1} was obtained from ($V_2 \times F_2 \times S_2$). The results concluded that different varieties with an application of the same fertilizers gave different mean values of P uptake in wheat straw, this may be due to genetic variation between them.

Table 9: Combination effect among micronutrient foliar application and growth stages on phosphorus uptake (kg ha^{-1}) in straw.

Variety	Stages	F_1	F_2	F_3	F_4	Varieties	Stages
V_1	S_1	3.66^{abc}	2.57^{bcd}	3.73^{ab}	2.77^{bcd}	3.49^{a}	S_1= 2.70^{b}
	S_2	3.53^{abc}	4.18^{a}	4.57^{a}	2.53^{cd}		
V_2	S_1	2.01^{d}	2.03^{d}	2.70^{bcd}	1.90^{d}	2.49^{b}	S_1= 3.29^{a}
	S_2	3.50^{abc}	1.73^{d}	4.20^{a}	2.05^{d}		
Fertilizer means		3.15^{b}	2.59^{bc}	3.83^{a}	2.31^{c}	Grdarasha	
V x S		3.21^{a}	3.78^{a}	2.18^{b}	2.80^{ab}		
V_1 x F		3.60^{ab}	3.37^{ab}	4.15^{a}	2.65^{bc}		
V_2 x F		2.75^{bc}	1.88^{c}	3.45^{ab}	1.98^{c}		
S_1 x F		2.79^{bc}	2.36^{bc}	3.21^{abc}	2.32^{bc}		
S_2 x F		3.51^{ab}	2.82^{bc}	4.45^{a}	2.31^{c}		

*Mean values followed by the same letter are not significantly different at the 5% probability level.

Table 10 shows the Phosphorous uptake by grain was significantly influenced by the treatment combination between varieties and growth stages V_1 at S_2 recorded the highest P uptake (8.39) kg ha^{-1} while V_2 at S_2 obtained the lowest P uptake (5.84) kg ha^{-1}. It was evident in the same table that treatment combinations ($V_1 \times F_4$) recorded the highest uptake of

Phosphorus (9.17) kg ha^{-1}, but the lowest P uptake (5.47) kg ha^{-1} obtained by treatment combination ($V_2 \times F_2$).

Table 10: Combination effect among micronutrient foliar application and growth stages on phosphorus uptake (kg ha^{-1}) in grains.

Variety	Stages	F_1	F_2	F_3	F_4	Varieties	Stages
V_1	S_1	4.83^{e}	7.45^{cd}	8.58^{c}	9.21^{a}	8.22^{a}	$S_1 = 7.78^{a}$
	S_2	6.33^{de}	8.83^{bc}	7.25^{cd}	9.13^{a}		
V_2	S_1	8.94^{b}	5.41^{e}	7.24^{cd}	7.13^{cd}	6.67^{b}	$S_2 = 7.11^{b}$
	S_2	7.32^{cd}	5.52^{e}	5.08^{e}	5.44^{e}		
Fertilizer means		7.00^{b}	6.77^{b}	7.03^{b}	8.80^{a}		
V x S		8.06^{a}	839^{a}	7.50^{ab}	5.84^{b}		
V_1 x F		5.58^{c}	8.14^{b}	7.92^{b}	9.17^{a}		
V_2 x F		8.63^{b}	5.47^{c}	6.16^{c}	6.29^{c}		
S_1 x F		7.16^{ab}	6.45^{b}	7.94^{ab}	9.44^{a}		
S_2 x F		6.84^{ab}	7.10^{ab}	6.11^{b}	8.17^{ab}		

*Mean values followed by the same letter are not significantly different at the 5% probability level.

Additionally, the combinations between fertilizers and growth stages showed significant differences in P uptake by grain. The maximum Phosphorus uptake (9.44) kg ha^{-1} was noted from the ($F_4 \times S_1$), whereas the lowest mean value (6.11) kg $ha^{-1}$was obtained from ($F_3 \times S_2$). Finally, the treatment combinations among the studied factors showed a significant difference, ($V_1 \times F_4 \times S_2$) recorded the highest Phosphorus uptake (9.21) kg ha^{-1} while ($V_1 \times F_1 \times S_1$) obtained the lowest mean value of P (4.83) kg ha^{-1}.

The phosphorus content in the grain was negatively and substantially affected by the singular application of iron. However, the micronutrient types were found to be in the order of Fe+ Zn > Zn > control > Fe. These results also indicated that the treatment (F_4) was more effective than solely application of (Fe and Zn), this may be due to the precipitation of FeSO4 on the root while in the case of Zn + Fe, the above precipitation decreased due to antagonistic relation between the two elements. Discerned findings of the different studies presented that spraying of Zn and the combination of (Zn + Fe) increased NPK uptake and their concentration in straw and grain respectively [14]. The utilization of P by wheat grain and straw increased significantly with lower levels of Fe over control, the highest level of iron caused a significant reduction in P uptake by wheat crop. This reduction may be due to a reduction in grain and straw production as mentioned by [28].

3.5 Potassium uptake in straw and grain (kg ha^{-1})

Table 11 illustrates that there was a significant effect of varieties on the K uptake by wheat straw. Different varieties showed different mean values of K uptakes, the highest and lowest values (3.64 and 2.35) kg ha^{-1} were recorded from (V_1) and (V_2) respectively. The fertilizers application also affected significantly, the highest K uptake (3.47) kg ha^{-1} received at (F_3) whereas, the lowest rate (2.31) g ha^{-1} was obtained at (F_4). Results of the same table recorded a significant difference in three second treatment combinations. The highest mean values were (4.23, 4.23 and 3.51) kg ha^{-1} which obtained from ($V_1 \times S_2$), ($V_1 \times F_2$) and (F_1 x S_2), while the lowest K uptake (2.20,1.77 and 2.07) kg ha^{-1} was achieved from ($V_1 \times S_2$), ($V_2 \times F_2$) and (F_4 x S_2) respectively. The three factor combinations showed significant differences in potassium uptake in wheat straw, ($V_1 \times F_2 \times S_2$) recorded the highest K uptake (4.80) kg ha^{-1} while, the treatment combinations ($V_2 \times F_2 \times S_1$) received the lowest mean value 1.54 kg ha^{-1}. Three-factor analysis of variance revealed that all sources of variations were significant except growth stages according to the F-test.

Table 12 explains the K uptake by wheat grain. V_1 recorded a higher mean value (10.58) kg ha^{-1} than V_2. As well as (F_2 and F_3) recorded the highest and lowest K uptake with values (12.01 and 8.41) kg $ha^{-1.}$ The treatment combinations ($V_1 \times F_2$) recorded the highest K uptake (11.49) kg ha^{-1} whereas, ($V_1 \times F_3$) noted the lowest amount (7.60) kg ha^{-1}. The data existing in the same table illustrated a significant difference among fertilizers and growth stages by grain. Maximum rate (11.35) kg ha^{-1} was received from ($F_4 \times S_1$) while, the least amount of Potassium uptake (6.73) kg ha^{-1} was noted from treatment combination ($F_1 \times S_2$). Finally, the highest and lowest K uptake in wheat grain (11.65 and 6.25) kg ha^{-1} were achieved from the treatment combinations ($V_1 \times F_2 \times S_2$) and ($V_2 \times F_3 \times S_1$) respectively.

The dendrogram was sketched from cluster analysis of micronutrients uptake based on 16 treatment combination of the studied factors (Figure 1and 2) in wheat straw (and Figure 3 and 4) in grain. The studied treatment combination was classified into clusters depending on similarity. The clusters were three in straw C1, C2 and C3 and four clusters in wheat grain which are C1, C2, C3 and C4.the classification was clear in the mentioned Table 13.

Table 11: Combination effect among micronutrient foliar application and growth stages on potassium uptake (kg ha^{-1}) in straw.

Variety	Stages	F_1	F_2	F_3	F_4	Varieties	Stages
V_1	S_1	2.26^{de}	3.66^{abc}	3.89^{ab}	2.52^{cde}	3.64^{a}	S_1=2.78^{a}
	S_2	4.36^{a}	4.80^{a}	4.54^{a}	2.60^{de}		
V_2	S_1	2.94^{bcd}	1.54^{e}	3.08^{bcd}	2.50^{de}	2.35^{b}	S_2= 3.21^{a}
	S_2	2.66^{cde}	1.99^{de}	2.50^{de}	1.59^{e}		
Fertilizer means		3.07^{a}	2.86^{a}	3.47^{a}	2.31^{b}		
V x S		3.06^{b}	4.23^{a}	2.50^{bc}	2.20^{c}		
V_1 x F		3.31^{ab}	4.23^{a}	4.21^{a}	2.56^{bc}		
V_2 x F		2.80^{bc}	1.77^{c}	2.7^{bc}	2.05^{c}		
S_1 x F		2.63^{ab}	2.48^{ab}	3.50^{a}	2.55^{ab}		
S_2 x F		3.51^{a}	3.24^{a}	3.44^{a}	2.07^{b}		

*Mean values followed by the same letter are not significantly different at the 5% probability level.

Table 12: Combination effect among micronutrient foliar application and growth stages on potassium uptake (kg ha^{-1}) in grains.

Variety	Stages	F_1	F_2	F_3	F_4	Varieties	Stages
V_1	S_1	11.10^{bcd}	11.32^{b}	7.91^{fg}	11.06^{b-e}	11.06^{a}	11.03^{a}
	S_2	6.25^{g}	11.65^{a}	7.28^{fg}	11.06^{bc}		
V_2	S_1	8.81^{d-g}	8.11^{e-g}	6.25^{g}	11.59^{a}	9.63^{b}	9.86 a
	S_2	7.17^{fg}	11.04^{cde}	11.16^{bc}	9.34^{c-f}		
Fertilizer means		8.55^{b}	11.20^{a}	8.41^{b}	11.18^{a}		
V x S		11.11^{a}	11.00^{a}	9.55^{a}	9.70^{a}		
V_1 x F		8.64^{cd}	11.49^{a}	7.60^{d}	11.06^{bc}		
V_2 x F		7.99^{cd}	9.27^{cd}	8.91^{cd}	11.26^{ab}		
S_1 x F		11.04^{bc}	11.07^{ab}	7.08^{cd}	11.35^{a}		
S_2 x F		6.73^{d}	11.33^{a}	9.74^{bcd}	11.00^{ab}		

*Mean values followed by the same letter are not significantly different at the 5% probability level.

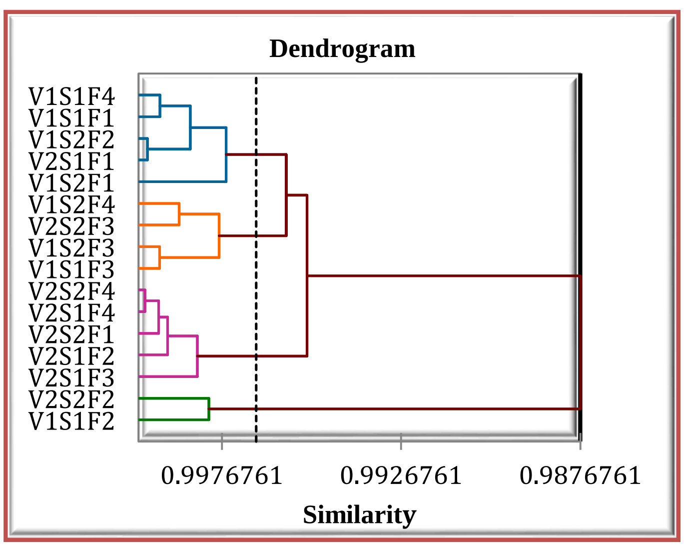

Figure 1: Dendrogram obtained from a cluster analysis of treatment combination in straw.

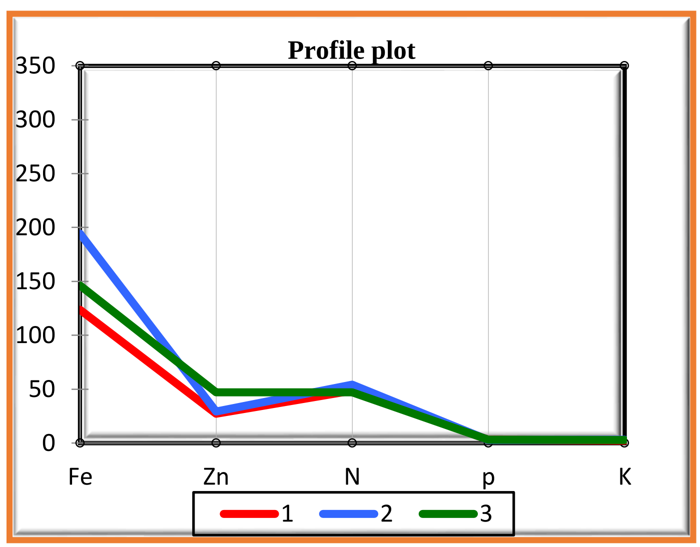

Figure 2: Profile plot of the nutrient uptake in straw.

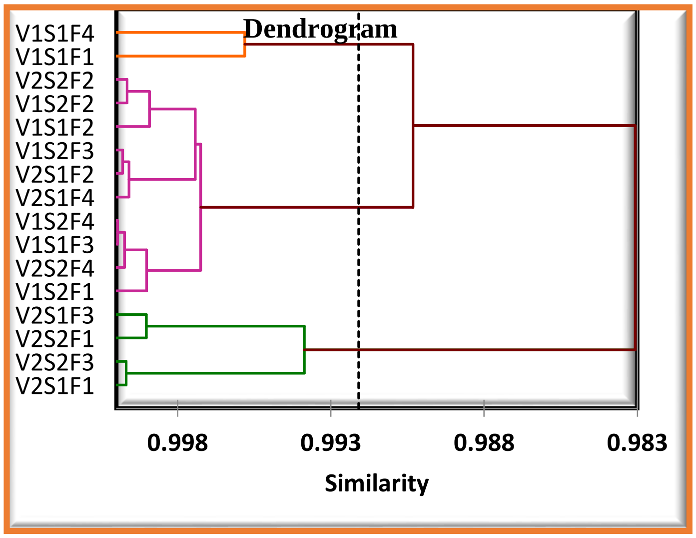

Figure 3. Dendrogram obtained from a cluster analysis of treatment combination in straw.

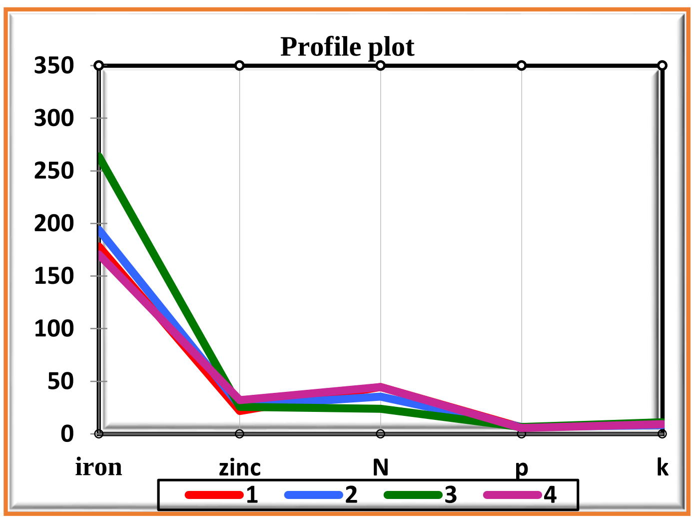

Figure 4. Profile plot of the nutrient uptake in grain.

It's clear that the closest distance means more similarity. The vertical lines are responsible for limiting the similarity between groups or dividing the studied characteristic. In real-life situations, clustering variables can be a useful way to discover which traits or groups of traits tend to vary together in a population. Figure 5 and 6 explain the vectors for the studied traits and the angles between vectors explain the correlation between them.

The decrease in angle value to < 90◦ means an increase in positive correlation coefficient value and if the angle approaches zero the correlation coefficient value approaches 1.00; if the angle is °90 that means the correlation coefficient equals zero. If it is °180, it means the correlation (r = -1) or open-angle between two variables decreases to a negative correlation between them. However, if the angle between two variables is less than °90, it means there is a positive correlation coefficient. The length of the vector explains the value of loading factors The combination treatments in Figure 5 give different explanations for the first group including P , N and Zn For the variables close to the center there will not be significant differences between them for example in is the closest variable the x-axis's have + ve value for example the axes number of nitrogen and phosphorous was 0.857 and 0.669 while Zn was a 0.417 .group 2 have negative y-axes and positive x-axes for Fe and K with values 0.754 and 0.565 with the same explanation for treatment combinations ,it means the distance between the locations of treatment combination and the origin explains the role of them ,increase in distance means increase the role and vice versa.

Table 13: Classify the treatment combination into clusters as shown below.

Observations	Class for straw (3 Clusters)	Observations	Class for grain (4 Clusters)
$V_1S_1F_1$	1	$V_1S_1F_1$	1
$V_1S_2F_1$	2	$V_1S_2F_1$	1
$V_2S_1F_1$	3	$V_2S_1F_1$	1
$V_2S_2F_1$	3	$V_2S_2F_1$	2
$V_1S_1F_2$	2	$V_1S_1F_2$	3
$V_1S_2F_2$	2	$V_1S_2F_2$	1
$V_2S_1F_2$	2	$V_2S_1F_2$	2
$V_2S_2F_2$	2	$V_2S_2F_2$	3
$V_1S_1F_3$	2	$V_1S_1F_3$	4
$V_1S_2F_3$	2	$V_1S_2F_3$	4
$V_2S_1F_3$	3	$V_2S_1F_3$	2
$V_2S_2F_3$	3	$V_2S_2F_3$	4
$V_1S_1F_4$	1	$V_1S_1F_4$	1
$V_1S_2F_4$	2	$V_1S_2F_4$	4
$V_2S_1F_4$	2	$V_2S_1F_4$	2
$V_2S_2F_4$	2	$V_2S_2F_4$	2

Figure 6. for the grain shows three groups K and Fe first group positive x and y, N and Zn both positive axis the second group positive x-axis and negative axis the third group had both negative axes with values (0.371 and 0.610) (0.345 and 0.419) and 0.256 respectively.

Fe application significantly caused an increase of K uptake in grain the results agreed with those found by [29]. Indicating Fe application alone or in combination with Zn had a positive result in terms of the grain potassium concentration and uptake. It was reported that application Fe +Zn increased the uptake of N, P, K, S, Zn and Fe in safflower [30]. The treatment combination $F_2\times S_2 \times V_1$ noted the highest value, these results support the finding made by [31] who reported that application treatment (Fe) recorded the highest values for K content in comparison to other treatments over two growth seasons.

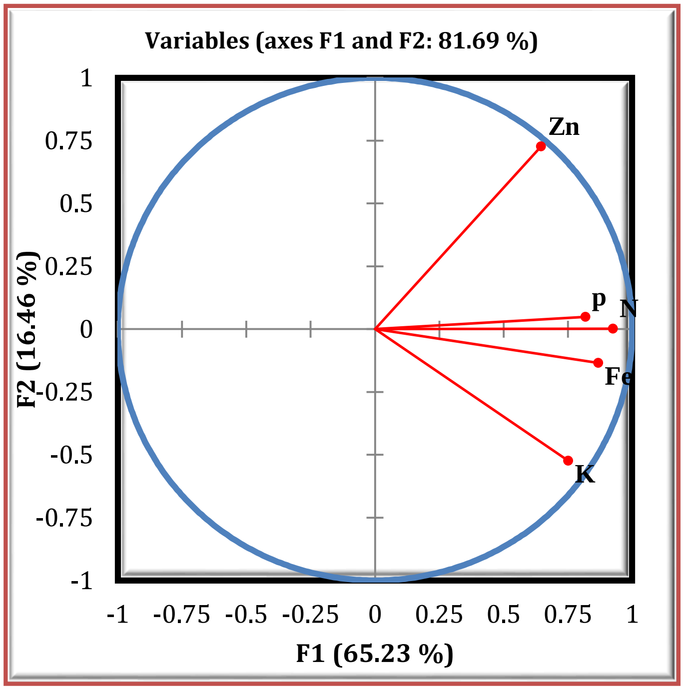

Figure 5: The vectors of the nutrient uptake.

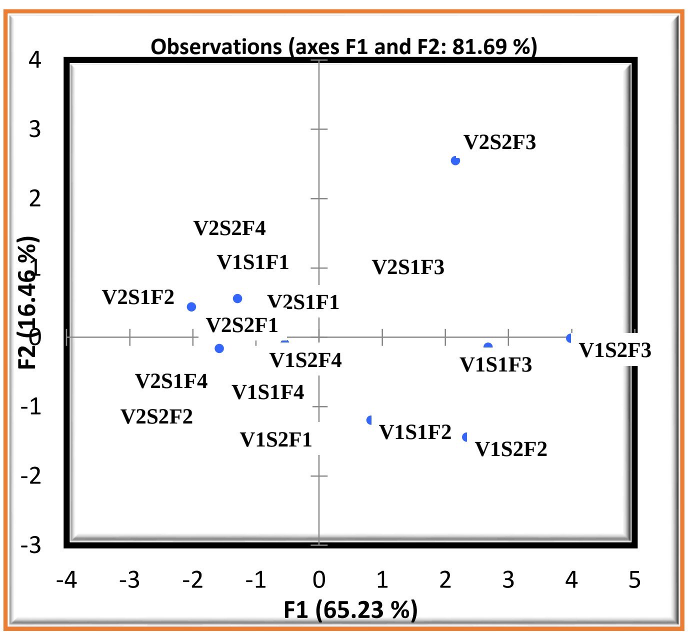

Figure 6: The vectors of the treatment in straw combinations in grain.

Conclusion

The study demonstrated that microelement treatments significantly influence nutrient uptake in wheat, with notable variations between wheat varieties, growth stages, and treatments. The Hawler 2 variety exhibited superior uptake of most nutrients compared to Hawler 4, suggesting a stronger physiological response to microelement applications. Growth stages had minimal impact on nutrient uptake, except for increased iron and phosphorus in grains at the tillering stage and elevated phosphorus in straw at the booting stage. Among the treatments, zinc application enhanced the uptake of most nutrients in straw and grains, while iron specifically improved potassium and iron uptake in grains. The combined application of iron and zinc significantly boosted nitrogen and phosphorus uptake in grains. These findings underline the importance of selecting appropriate wheat varieties and optimizing microelement fertilization strategies to improve nutrient uptake and overall crop performance. Further studies on the long-term impacts of these treatments and their interaction with other environmental factors are recommended.

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