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# ECONOMIC FEASIBILITY OF SUPPLEMENTARY FOLIAR FERTILIZATION FOR WHEAT CULTIVARS UNDER RAINFED CONDITIONS

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**Abstract**

At the beginning of any growing season, farmers' decision for selecting a profitable crop depends mainly on marketing and marginal rate of return. Selecting high yield and profitable wheat cultivar and production practices such as fertilization and in order to propose acceptable recommendations for farmers, a combination between soil and foliar application of fertilizers to investigate the growth and yield of different wheat cultivars in relation to economic feasibility and profitability was planned. Accordingly, this study was conducted during the growing seasons 2019/2020 in Duhok area to study the economic feasibility of supplementary foliar fertilization for different cultivars of wheat as well as studying their growth and yield performance under rainfed environments. Five wheat cultivars (Adana99, Ceyhan-99, Tamoz, Creso, IRIDE) and four forms of fertilization: control, conventional DAP, Foliar fertilizer EcoZink and both DAP plus foliar fertilizers were suggested as the study factors with four replications arranged in Randomized Complete Block Design and data were analyzed using computing application of GenStat program.

Results showed promising findings. All growth and mainly spike characters were improved differently by fertilizer application and also reflected positively on the final grain yield. The final grain yield was increased significantly by fertilization in which DAP plus Foliar fertilizer recorded highest grain yield (5.59 $t.ha^{-1}$) followed by Foliar and DAP fertilizers and each gave 5.22 and 4.82 compared to 3.87 for control treatment respectively. It's also observed that the revenue or outcome for all wheat cultivars was high in all fertilizer treatments compared to non fertilization of control treatment; DAP plus Foliar gave highest revenue (1930.97 $\$.ha^{-1}$) followed by Foliar and then DAP fertilizer treatments. On the other hand, higher outcome not meaning higher profitability and according to the economic and marginal rate of return analyses, spending every single unit of US$ from Foliar fertilization gained 182.91 $ compared to 13.8$ and 12.2$ for each of DAP plus Foliar and DAP treatments, respectively. Based on the spike characters and yield improvements by foliar fertilization and high marginal rate of retune, supplementary application of Foliar EcoZink alone or with DAP fertilizer is highly recommended for the farmers and also further studies are suggested in similar conditions and on other types of foliar fertilization to support the obtained findings in this study.

**Key words:** Economic feasibility, Foliar fertilization, Yield, Profitability.

## Introduction

To propose acceptable recommendations for farmers, researchers must think in terms of farmers' goals and the obstacles achieving these goals; as farmers concern for food supply and economic return to their families, they respond to changes and apply new technology gradually after comparing with rival alternatives. Furthermore, switching from traditional agriculture is not fluent in most world areas; due to resources, climate change, conflicts and locations, the conventional agriculture and tools will stay a major economic facility for many most of world population (Anon., 1988). However, new employment and income generating opportunities are critically needed in rural areas. In Iraq and Kurdistan region in particular, wheat is the dominant cultivated crop, depending mainly on the annual rainfall which usually occur within the beginning of November to the mid of May which is characterized by instability in raining rate and distribution; this and along with low potential varieties, conventional fertilizer application and other cultural practices are the main reasons of low yield for wheat crop in rainfed areas of Iraq (Khalaf & Omer, 2018). In this regards, Anon., (2020) reported that the average yield of wheat for the period of 2009 – 2018 was only 855 kg per hectare in Iraqi Kurdistan region areas. Globally, wheat is the most important food security crop because for its direct impact on minimizing food scarcity along with population growths and securing daily gap for about 35% of the world's areas (Mahmood *et al*., 2018 and Rijib & Jbara, 2016). Mustafa and Jbara (2018) reported that despite the endeavor for increasing world wheat yield, the total production is still under the ambitions that ensure to match the increasing consumption requirements.

Conventional application of fertilization and mainly soil treatment of NPK has been reported by Stapper *et al*., (1989), Salimpour *et al*., (2010), Karem *et al*., (2012), Zou *et al*., (2012), Harfe (2017) and Belete *et al*., (2018) for various wheat cultivars and they reported significant increases of growth and yield of wheat. Because of the intensive cropping systems, a great depletion of nutrients from soils is occurring; the soil nutrient content may not be always enough to match the crop development requirements (Hussain *et al*., 2006); and this urge wheat growers to apply higher amount of fertilizers that reflects on their economic income and soil contamination. Similarly, Foth & Ellis (1996) reported that most of micro-nutrients such as Fe, Ca, Mg, and Mn are easily fixed in alkaline soils; plant roots are not capable to absorb them adequately from soil and hinder their translocation to the leaves. Foliar fertilization can be similar and more effective as soil fertilization is used effectively for overcoming the deficiency of some nutrients in soil (Torun *et. al*., 2001). In this regards, Liew (1988) proposed an increase of crop production from 6 to 20 times more for foliar compared to soil fertilization. Also, Deepa *et al*., (2019) and Kumar *et al*., (2018) recorded significant increases of both growth and yield of cereals in response to the foliar fertilization. Dobbs (1988) stated some interacted and interrelated economic feasibility components: estimating costs; testing available market products; price analysis; and analysis of potential profits. These factors should carefully study and involve in any business plan. Agami *et al.*, (2018) demonstrated that the effect of foliar application of nitrogen fertilizer was significant on grain filling and starch accumulation. These findings might be valuable for wheat production under climate change suggesting that leaves were more efficient at absorbing nutrients during the later stages of wheat growth.

It is noted during our observations in farmers' fields that they used to apply only soil fertilizers to their fields of wheat, but when they advised to apply some available kinds of foliar fertilizers and mainly at the end of the crop's life (physiological repining stage), significant improvements of yield were observed. Based on these initial observations, it realized that the yield of wheat can be improved by improving varietal and cultural practices especially fertilization. Therefore, the idea of this study was inspired to combine both soil and foliar application of fertilizers to investigate the growth and yield of different wheat cultivars in relation to economic feasibility and profitability as the farmers are usually concerned about the high costs of fertilizer applications.

## Materials and Methods

This study was conducted during the growing seasons 2019/2020 in Duhok area to study the economic feasibility of supplementary foliar fertilization for different cultivars of wheat as well as studying their growth and yield performance under rainfed environments. Five wheat cultivars (*T. aestivum* L.; Ceyhan-99 (pedigree: BJY"S"/ COC) and Adana99 (pedigree: PFAU/SERI-M-82//BOBWHITE) origin Turkey, Tamoz local, and *Triticum durum* Desf. Creso (pedigree: Cp B 14 (Yt 54-N10-B)/Cp 632)/TC 603) and IRIDE (pedigree: Altar 84/Ionio) origin Italy (Maccaferri *et al.*, 2007) were selected in which all, excluding IRIDE, are the commonly cultivated types among farmers in Duhok region. Also, four forms of fertilization**:** Control (without any treatments), Conventional NPK soil fertilizer in the form of DAP 18:46:0, 120 kg.ha$^{-1}$ at the sowing day, liquid form of organic fertilizer EcoZink imported from Turkey by Green life company which consist of 1.15% Zn, 8.20% N, 10.90% Humic and Fulvic acid, 20% OM, 8.93% Organic Carbon, 4.25 K, 0.12 Mn, 0.012 Cu, 0.013 B, etc. which sprayed as Foliar after setting stage at the early April in a rate of 5000 ml.ha$^{-1}$, and both DAP plus Foliar fertilizer at the mentioned times were suggested as the study factors with four replications.

The study designed as Split Plots in Randomized Complete Block Design; wheat cultivars stated as main plots and fertilizer treatments as sub-plots. The climate data were collected from the College of Agricultural Engineering Sciences meteorological station, the nearest station to the study site (Table 1).

The land was plowed two weeks prior sowing day by disc plow. Sowing date was at the last week of November 2019. Physical and chemical analysis tests were carried out for the soil samples collected randomly from 0-30 cm depth. All soil properties analysis was conducted at the University of Duhok, College of Agricultural Engineering Sciences/Central Laboratory (Table 1). Plot size was 6 m² (Six rows of 5 m long and 1.2 m width; 20 cm between rows) which are matching the seeding rate of 125 kg.ha$^{-1}$ based on germination and weight of 1000 grains (seeds for each line were separated, 12.5g to control the sowing process accurately). Distance between units was 0.5 m and 1m between replications. Weeding was conducted manually when required. At the time of data measurements; ten guarded plants from one of the middle rows were measured and then the average per one plant was calculated. All possible growth and yield related traits were measured at time. The crop was harvested in the second week of June. The data were analyzed using GenStat (2011) version 10 program. Duncan Multiple Range Test at level 0.05 was used for the mean comparisons.

**Economic feasibility and Marginal rate of return:** The costs for each agronomic and cultural practice were carefully recorded for a particular type of fertilization. Also, financial analysis was determined based on the current costs and prices in local markets for each wheat cultivar at each particular applied fertilizer; the net profitability per hectare was calculated by diminishing the total grain yield for each cultivar with the total costs. The net profit per hectare (Change in profits) was calculated based on method applied by *Iqbal et Al.*, (2010) and as follow:

**Change in Profits** ($) = Outcome.ha$^{-1}$ – Total costs.ha$^{-1}$ ….. (1)

**Table 1. Meteorological data of the site of experiment.**

| Growing season 2019/2020 | Months | Rainfall (mm) | Temperature C° | | Soil characteristics | |
|---|---|---|---|---|---|---|
| | | | Max. | Min. | Characteristics | Value |
| 2019 | Oct. | 3 | 30.8 | 18.2 | pH | 8.01 |
| 2019 | Nov. | 30 | 22.1 | 9.3 | N | 130 mg.kg-1 |
| 2019 | Dec. | 107 | 14.6 | 6.9 | P | 6.13 mg.kg-1 |
| 2020 | Jan. | 89.5 | 10.6 | 4.1 | K | 4.8 mg.kg-1 |
| 2020 | Feb. | 76 | 11.7 | 4.3 | OM (%)* | 1.21% |
| 2020 | Mar. | 310 | 18.6 | 9.8 | Sand (%) | 43.1 |
| 2020 | Apr. | 55 | 19.8 | 10.7 | Silt (%) | 33.4 |
| 2020 | May | 16.5 | 21.2 | 11.6 | Clay (%) | 23.5 |
| Total rainfall (mm) | | 687 | | | Soil texture | Loam |

* OM, Organic material

Increasing the final yield not necessarily mean higher profits, as the marginal rate of return which means the amount of income (return) that is generated if a single unit of the factor is added to the production process. Therefore, costs such as seeds, plowing, planting costs, weed and pest control, harvesting, etc. that do not differ across treatments (fixed costs) will be incurred regardless of which treatment is used; they do not affect the farmer's choices concerning fertilization and can be ignored for the purpose of this decision. As mentioned, not all production costs are included in the equation budget, only those are included that are affected by the alternative treatments being considered or the costs of fertilizers per unit area (Iqbal *et al.*, 2010). Accordingly, economic and marginal analyses were then determined following the equation developed by Byerlee (1988).

$$\textbf{Marginal rate of return (\%)} = \frac{Change\ in\ profits}{Change\ in\ costs\ (variable\ costs)} * 100 \quad \ldots\ldots\ldots\ldots (2)$$

**Table 2. Average values for plant height (Cm) of wheat cultivars under various fertilizers application.**

| Wheat cultivars | Fertilizer treatments | | | | Mean of wheat cultivars |
|---|---|---|---|---|---|
| | Control | DAP | Foliar | DAP+Foliar | |
| Adana99 | 74.33 fg | 82.67 cd | 92.11 ab | 87.78 bc | 84.22 a |
| Ceyhan-99 | 76.33 efg | 79.22 def | 79.67 def | 81.00 de | 79.06 b |
| Tamoz | 68.22 hi | 87.33 bc | 94.22 a | 92.67 ab | 85.61 a |
| Creso | 65.22 hij | 71.00 gh | 66.33 hij | 70.56 gh | 68.28 c |
| IRIDE | 56.11 l | 61.33 jkl | 58.33 kl | 64.11 ijk | 59.97 d |
| **Mean of fertilizers** | 68.04 c | 76.31 b | 78.13 ab | 79.22 a | |

* Within each column or rows, numbers sharing the same letters not significantly differ according to Duncan Multiple Range Test at probability 0.05

**Table 3. Average values for flag leaf area ($cm^2$) of wheat cultivars under various fertilizers application.**

| Wheat cultivars | Fertilizer treatments | | | | Mean of wheat cultivars |
|---|---|---|---|---|---|
| | Control | DAP | Foliar | DAP+Foliar | |
| Adana99 | 21.58 g | 30.82 bcdef | 33.48 bcde | 34.54 bcd | 30.11 bc |
| Ceyhan-99 | 25.67 defg | 30.41 bcdefg | 30.39 bcdefg | 35.49 bc | 30.49 bc |
| Tamoz | 25.66 defg | 33.84 bcde | 35.04 bc | 33.24 bcde | 31.95 b |
| Creso | 39.40 ab | 39.10 ab | 38.91 ab | 44.50 a | 40.48 a |
| IRIDE | 27.56 cdefg | 30.30 bcdefg | 23.76 fg | 25.00 efg | 26.66 c |
| Mean of fertilizers | 27.98 b | 32.90 a | 32.32 a | 34.55 a | |

* Within each column or rows, numbers sharing the same letters not significantly differ according to Duncan Multiple Range Test at probability 0.05

## Results and Discussions

**Growth characteristics:** Tables 2 and 3 show significant differences among wheat cultivars, fertilizer treatments and their interactions on each of plant height and flag leaf area characters. For plant height, all bread wheats surpassed durum cultivars in which Tamoz and Adana99 recorded tallest plants having height of 85.6 and 84.2 cm respectively and both Creso (68.2 cm) and IRIDE (59.9 cm) recorded shortest plants. Plants are usually differing in height due to the genetic factors as this trait is controlled by specific genes (Richards, 1992 and Robertson & Lowry, 2015). On the other hand, Creso cultivar was superior in flag leaf area (40.48 $cm^2$) and IRIDE was inferior with only 26.6 $cm^2$, followed by all other three bread cultivars.

In addition to genetic concerns, wheat growth and development is also influenced by growth circumstances surrounding the plant and mainly soil nutrition and fertilization (Deepa *et al.*, 2019 and Kumar *et al.*, 2018). Same tables (2 and 3) display significant effects of fertilizer treatments and forms on both plant height and flag leaf area. All fertilizer treatments enhanced wheat growth compared to control unit. Both of supplementary application of foliar fertilizer and DAP plus Foliar produced highest values 79.2 cm and 34.5 $cm^2$ for each of plant height and flag leaf area compared to 68.04 cm and 27.9 $cm^2$ respectively in control treatment.

The interaction of wheat cultivars with fertilizer treatments was also significant for both plant height and flag leaf area (Tables 2 & 3), the interaction of Tamoz cultivar with both foliar (94.2 cm) and DAP plus Foliar (92.67 cm) was the dominant in plant height, while Creso with the same fertilizer treatments recorded better flag leaf area (38.91 and 44.5 $cm^2$ respectively). Most growth characteristics correlated positively with final grain yield (Table 8).

**Spike characteristics:** As it's expected from the initial experience of farmers fields that most of fertilizer treatments and mainly foliar application will reflect directly on the spike characters compared to other forms, due to the direct reach of nutrient through foliar spraying to the leaves and other parts of the plant (Kumar *et al.*, 2018). In addition of the final grain yield, the focus in this study was also on spike traits especially spike density and biomass, where the results are presented in Tables 4 & 5 and spike length in Figure 1. All bread wheats recorded higher spike biomass compared to durums. Tamoz cultivar was the superior and Crios was inferior with 13.38 and 8.96 $gm.spike^{-1}$ respectively. In contrast to the spike biomass trait, the spike density was better in durum wheats as the number of seeds per spike for durum cultivars is more than in bread types because of the short distances between the spikelets within the spike. Accordingly, each of Creso; (81.96) and IRIDE; (76.45) seeds.10cm$^{-1}$ cultivars significantly recorded higher spike densities compared to around 41-47 seeds.10cm$^{-1}$ for the bread cultivars, meanwhile the effect of fertilizers on spike density was not significant (Table 5). The differences of wheat cultivars and types in spike density is related to their genetic background (Robertson and Lowry, 2015). On the other hand, the spike biomass is affected by the environmental conditions and soil fertility status and therefore, it was significantly enhanced with the application of fertilization compared to control treatment. Both foliar and DAP plus Foliar treatments significantly increased spike biomass compared to other treatments and each gave 11.63 and 11.42 g.spike$^{-1}$, respectively. With the same direction of spike density and spike length values were higher in bread wheats compared to durums (Fig. 1). Also, spike length was affected significantly with the application of fertilizer with each of Foliar and DAP plus Foliar in the top followed by DAP applied alone and control unit in the bottom.

The obtained results indicate significant influence of supplementary foliar fertilizer with DAP or its single application improving the spike characters which then reflect positively on the final grain yield and farmers income (Fig. 2). Improving of growth and spike characteristics by foliar fertilizers has also been reported by Atab *et al*., (2019), Arif *et al*., (2006), Torun *et. al*., (2001), Deepa *et al*., (2019) and Kumar *et al*., (2018). The impact of foliar fertilizer is due to their rapid absorption and contributing in grain filling and starch accumulation because leaves at the end stage of plant are more effective for absorbing nutrients than senescence roots at the same stage (Agami *et al*., 2018).

**Yield and its components characteristics:** Wheat cultivars and growing conditions such as fertilization, affect the final grain yield and related components differently. Grain yield is dissected into its main components; number of tillers per unit area, number and weight of grains are the direct traits in which the final grain yield depends.

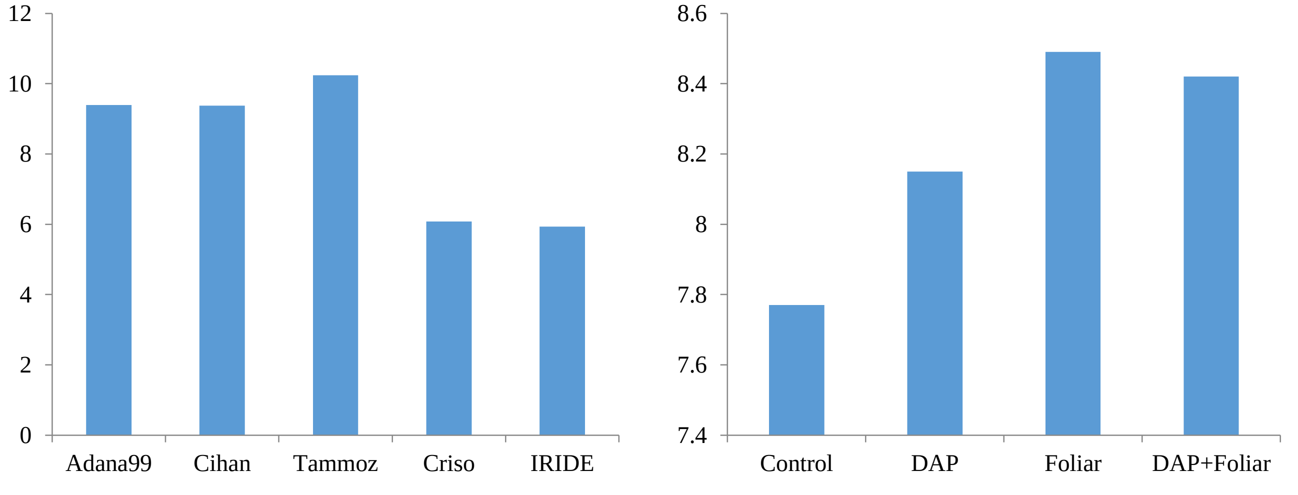


Fig. 1. Spike length (cm) for wheat cultivars in respond to the fertilization.

**Table 4. Average values for spike biomass (SPBIO) gm.spike$^{-1}$ of wheat cultivars under various fertilizers application.**

| Wheat cultivars | Fertilizer treatments | | | | Mean of wheat cultivars |
|---|---|---|---|---|---|
| | Control | DAP | Foliar | DAP + Foliar | |
| Adana99 | 12.14 abc | 10.53 abc | 15.93 ab | 9.88 abc | 12.12 ab |
| Ceyhan-99 | 9.52 abc | 11.48 abc | 12.63 abc | 9.78 abc | 10.85 ab |
| Tamoz | 16.90 a | 8.46 abc | 13.12 abc | 15.04 abc | 13.38 a |
| Creso | 7.49 bc | 8.33 abc | 7.93 bc | 12.09 abc | 8.96 b |
| IRIDE | 6.62 c | 10.85 abc | 8.52 abc | 10.31 abc | 9.07 b |
| Mean of fertilizers | 10.53 b | 9.93 b | 11.63 a | 11.42 a | |

* Within each column or rows, numbers sharing the same letters not significantly differ according to Duncan Multiple Range Test at probability 0.05

**Table 5. Average values for spike density (grains.10cm$^{-1}$) of wheat cultivars under various fertilizers application.**

| Wheat cultivars | Fertilizer treatments | | | | Mean of wheat cultivars |
|---|---|---|---|---|---|
| | Control | DAP | Foliar | DAP+Foliar | |
| Adana99 | 38.37 b | 42.68 b | 42.41 b | 41.05 b | 41.13 b |
| Ceyhan-99 | 42.51 b | 42.89 b | 51.12 b | 47.29 b | 45.95 b |
| Tamoz | 51.91 b | 41.19 b | 47.96 b | 49.85 b | 47.73 b |
| Creso | 85.22 a | 76.11 a | 89.04 a | 77.46 a | 81.96 a |
| IRIDE | 77.85 a | 70.73 a | 69.61 a | 87.61 a | 76.45 a |
| Mean of fertilizers | 59.17 a | 54.72 a | 60.03 a | 60.65 a | |

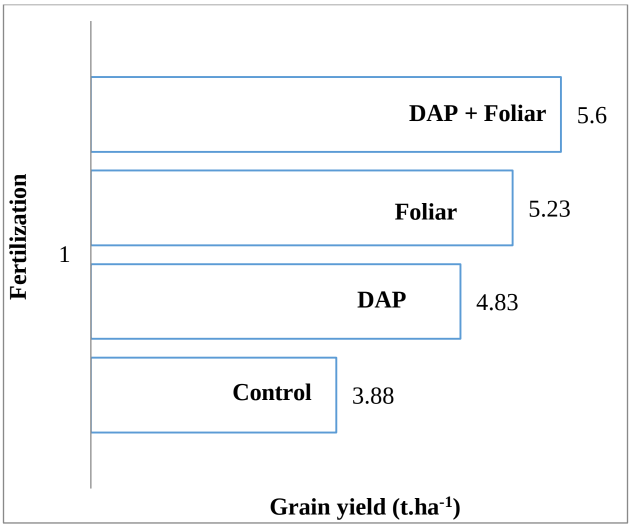


Fig. 2. Mean of final grain yield (t.ha$^{-1}$) for each applied fertilizers.

**Number of tillers (spike.m$^{-2}$):** The number of fertile tillers (spikes per area unit) was generally lowest in durum and highest in bread cultivars (Table 6). Both Adana99 and Tamoz cultivars produced the highest number of fertile tillers, each with 313 tillers.m$^{-2}$ followed by Ceyhan-99. On the other hand, Creso cultivar produced lowest number of tillers (192.5).

All types of fertilization significantly increased tillering in wheat cultivars (Table 6). Supplementary application of Foliar and DAP fertilization produced the highest number of fertile tillers (297.7 tillers.m$^{-2}$) followed by other fertilizers forms compared to control treatment. The interaction of each superior cultivars (Adana99 and Tamoz) with both Foliar and DAP plus Foliar enhanced the production of tillers per unit area and inferior cultivars (Creso) in control treatment was the lowest with only 165.7 tillers.m$^{-2}$. Number of tillers was positively correlated to the final grain yield (*r=0.72***) indicating the importance of this trait for farmers income (Table 8).

**Weight and number of Grains:** Weight and number of grains per unit area make up the total grain yield and are influenced by agronomic conditions such as cultivars and fertilization. Regarding number of grains per spike, they are well described within the spike density character (Table 5) as it resembles the same trait.

For the 1000-grain weight trait, the differences among wheat cultivars were observed. Creso cultivar with 51.9 gm surpassed all others in this trait and Tamoz produced lowest value (34.5 gm), while the other three cultivars did not differ significantly. However, both Foliar and DAP plus Foliar fertilization recorded higher values of grain weight, the main effect of fertilization was not significant (Table 7). Similarly, the interaction of both Creso and Tamoz cultivars with all treatments was the highest and lowest, respectively.

**Final grain yield:** The final grain yield data are displayed in Figures 2 & 3. The effect of wheat cultivars was not significant while fertilization showed significant differences in which DAP plus Foliar treatment recorded highest grain yield (5.59 t.ha$^{-1}$), followed by Foliar and DAP fertilization and each gave 5.22 and 4.82 compared to 3.87 for control treatment respectively. Also, the interaction of wheat cultivars with fertilization was significant. Ceyhan-99 in Foliar (7.63) and both Tamoz (6.79) and Creso (6.48) interaction with DAP plus Foliar fertilization were the superior treatments for giving highest final grain yield. The superiority of each of Ceyhan-99 and Tamoz cultivars in final grain yield correlated to their superiority in producing higher number of tillers per unit area (Table 6) while weight of 1000 grains contributed for the superiority of Creso cultivar (Table 7). It is observed that final grain yield was highly correlated with number of tillers (*r=0.72***) and spike biomass (*r=0.78***). Moreover, growth characters such flag leaf correlated positively (*r=0.33**) with final grain yield (Table 8).

The Biplot analysis also displayed the aggregation of each of Adan99, Ceyhan-99 and IRIDE cultivars with DAP fertilize while Adana99 and Tamoz were close to Foliar. On the other hand, Tamoz, Creso and IRIDE also created a triangle in DAP plus Foliar treatment (Fig. 3). The biplot analysis has similar trend and supporting the results as reported in Figure (3).

As described that growth factors and mainly spike characteristics which contributed for enhancing final grain yield are also improved remarkably by supplementary application of foliar fertilization at the setting and spike development stages giving an inspiration that if economically sounds that will be declared in this study through economic feasibility section, application or supplementary application of foliar fertilizer will be highly recommended. Carver *et al.*, (2017) also reported significant increases of wheat final grain yield through application of different sources and methods of fertilization.

**Table 6. Average values for number of tillers.m$^{-2}$ of wheat cultivars under various fertilizers application**

| Wheat cultivars | Fertilizer treatments | | | | Mean of wheat cultivars |
|---|---|---|---|---|---|
| | Control | DAP | Foliar | DAP+F | |
| Adana99 | 239.7 defghi | 300.3 bcde | 435.0 a | 278.0 cdef | 313.3 a |
| Ceyhan-99 | 294.3 cde | 345.3 bc | 224.7efghi | 286.0 cdef | 287.6 ab |
| Tamoz | 290.3 cdef | 245.0 defgh | 329.7 bcd | 387.7 ab | 313.2 a |
| Creso | 149.3 i | 174.3 ghi | 196.0 fghi | 250.3 cdefgh | 192.5 c |
| IRIDE | 165.7 hi | 287.3 cdef | 259.7 cdefg | 286.3 cdef | 249.8 b |
| Mean of fertilizers | 227.9 b | 270.5 a | 289.0 a | 297.7 a | |

* Within each column or rows, numbers sharing the same letters not significantly differ according to Duncan Multiple Range Test at probability 0.05

**Table 7. Average values for 1000 grain weight of wheat cultivars under various fertilizers application.**

| Wheat Cultivars | Fertilizer treatments | | | | Mean of wheat cultivars |
|---|---|---|---|---|---|
| | Control | DAP | Foliar | DAP+Foliar | |
| Adana99 | 37.87 bc | 38.40 bc | 39.33 b | 37.73 bc | 38.33 b |
| Ceyhan-99 | 39.47 b | 38.40 bc | 36.13 bc | 37.20 bc | 37.80 b |
| Tamoz | 34.00 bc | 35.20 bc | 35.47 bc | 33.47 c | 34.53 c |
| Creso | 52.80 a | 52.40 a | 51.60 a | 50.80 a | 51.90 a |
| IRIDE | 37.07 bc | 39.33 b | 36.00 bc | 38.40 bc | 37.70 b |
| Mean of fertilizers | 39.71 a | 39.52 a | 40.75 a | 40.24 a | |

* Within each column or rows, numbers sharing the same letters not significantly differ according to Duncan Multiple Range Test at probability 0.05

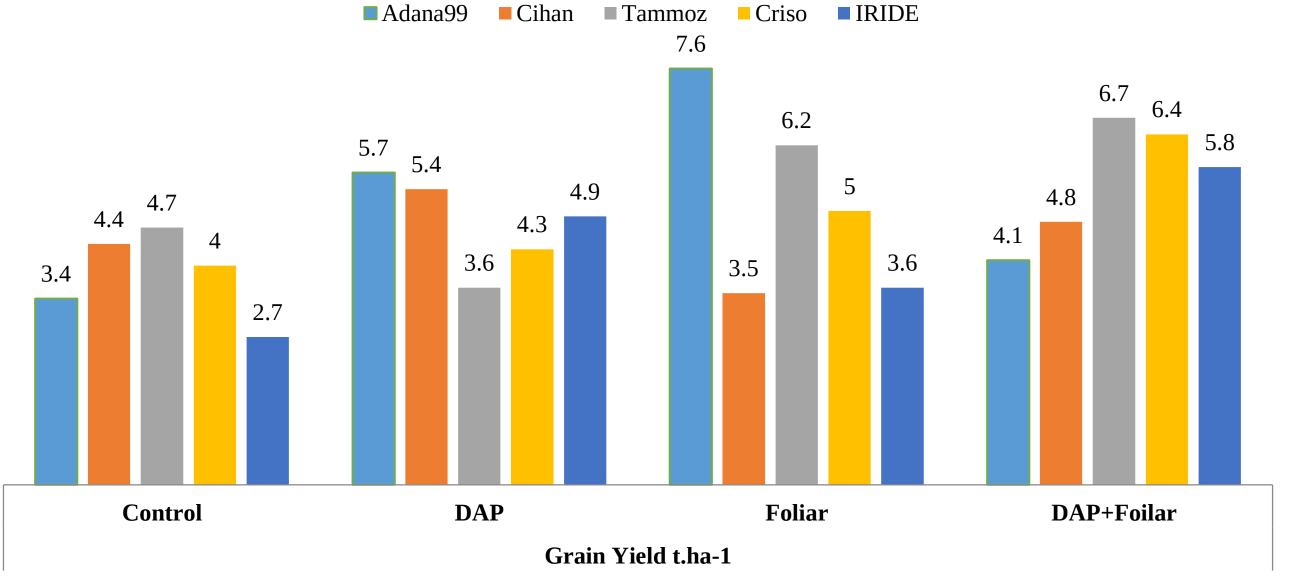


Fig. 3. Final grain yield (t.ha$^{-1}$) for the interaction of wheat cultivars in respond to the fertilization.

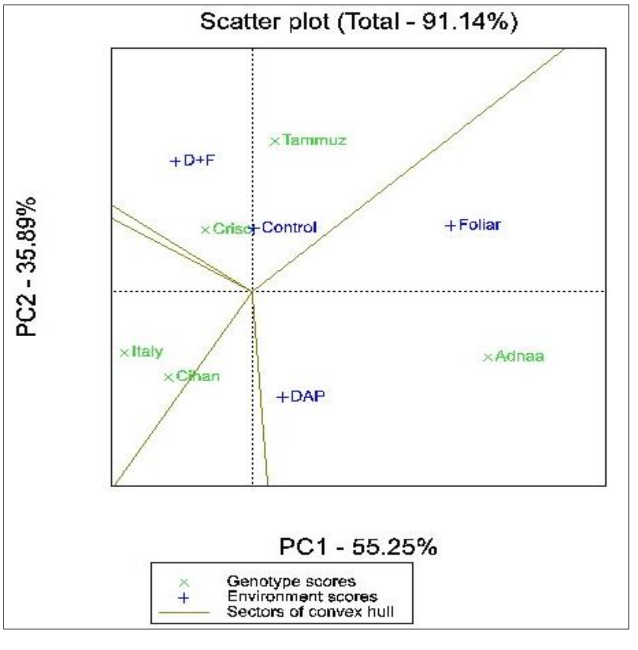


Fig. 4. Biplot (PC1 vs PC2) of final grain yield traits.

**Economic feasibility analysis and marginal rate of return:** Farmer's decision for selecting a profitable crop season depends mainly on marketing and marginal rate of return when starting sowing any crop. Absence of sufficient marketing and crop processing through industry sector caused real loss of the farmers' product which reduced their income and subsequently their demands for agriculture, therefore, any improvements in reducing costs and increasing yield will promote them to adopt immediately.

It's observed from the data (Table 9 & Fig. 5) that the revenue or outcome for all wheat cultivars was high in all fertilizer treatments compared to untreated unit in which DAP plus Foliar gave highest revenue (1930.97 \$.ha$^{-1}$) followed by Foliar and then DAP fertilizer treatments. On the other hand, higher outcome does not mean higher profitability and according to the economic and marginal analyses following the equation by Byerlee (1988) and Iqbal *et al.*, (2010), spending each single of US\$ from Foliar fertilization, earned 182.91 \$ compared to 13.8\$ and 12.2\$ for each of DAP plus Foliar and DAP treatments respectively (Table 9). Based on the spike characters (Tables 4, 5 and Fig. 1) and yield improvements (Tables 6, 7 and Figs. 2-4) by foliar fertilization and high marginal rate of return, supplementary application of Foliar Eco Zink alone or with DAP fertilizer is highly recommended for the farmers and also further studies are suggested in similar conditions and on other types of foliar fertilization to further verify the obtained results in this study. These results are in line with those of Liew (1988) who proposed an increase of crop production 6 to 20 times more for foliar compared to soil fertilization and with the suggestions of Torun *et al.*, (2001) whom proposed that foliar can be similar or more effective than soil fertilization for increasing the wheat production. Similar results were also found by each of Mehta (2020) and (Mikos-Szymańska *et al.*, 2018) for foliar application of fertilizers on wheat crop.

**Table 8. Correlation coefficients among some studied traits.**

| # | GYLD | THGW | NT | SPD | SPLGTH | PH | FLA |
|---|---|---|---|---|---|---|---|
| THGW | 0.09ns | | | | | | |
| NT | 0.72** | -0.46** | | | | | |
| SPD | 0.17ns | 0.55** | -0.41** | | | | |
| SPLGTH | 0.29ns | -0.55** | 0.58** | -0.83** | | | |
| PH | 0.33* | -0.34** | 0.53** | -0.69** | 0.89** | | |
| FLA | 0.30* | 0.49** | -0.05ns | 0.25ns | -0.05ns | 0.17ns | |
| SPBIOM | 0.78** | -0.17ns | 0.79** | -0.16ns | 0.41** | 0.41** | 0.07ns |

THGW; 1000 grain weight, NT; Number of tillers, SPD; Spike density, SPLGTH; Spike length, PH; Plant height, FLA; Flag leaf area, SPBIOM; Spike biomass

**Table 9. Economic feasibility analysis and marginal rate of return.**

| Production inputs (per hectare) | Fixed costs per hectare ($) | Applied fertilizers | Change in costs (variable) ($.ha$^{-1}$) | Total cost per hectare | Yield per hectare (ton) | Market price per ton ($) | Outcome per hectare ($) | Change in profits ($) | Marginal rate of return (%) |
|---|---|---|---|---|---|---|---|---|---|
| Seeds+Plowing | 100+48 | Control | 0 | 332 | 3.878 | 345 | 1337.91 | 1005.91 | ------ |
| Fertilizer | ------ | DAP | 100 | 432 | 4.827 | 345 | 1665.32 | 1233.32 | 1233.3 |
| Weeds+Pest control | 52+64 | Foliar | 8 | 340 | 5.227 | 345 | 1803.32 | 1463.32 | 18291.5 |
| Harvesting | 48 | DAP + Foliar | 108 | 440 | 5.597 | 345 | 1930.97 | 1490.97 | 1380.5 |
| Other costs | 20 | | | | | | | | |
| **Total costs** | **332** | | | | | | | | |

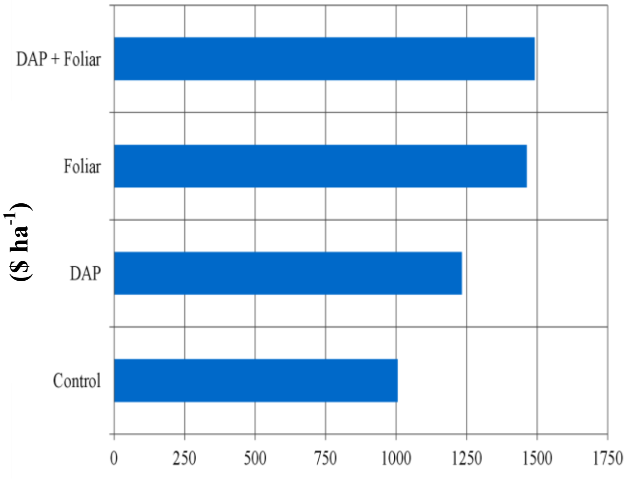


Fig. 5. Change in profit ($.ha$^{-1}$) for the fertilizers applided in this study

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