Response of Wheat to Foliar and Soil P Fertilization on Grain Yield and Phosphorus use Efficiency in Southeastern Algeria

N. Boukhalfa-Deraoui, L. Hanifi-Mekliche1, A. Mekliche

ABSTRACT

Background: P deficiency is very common in alkaline - calcareous soil. Therefore, application of foliar-absorbed fertilizers may be an effective strategy to overcome the low bioavailability of phosphorus in soil, by improving phosphorus use efficiency and reduced nutrients losses.

Methods: A field experiment was carried out in 2006-07 growing season at El-Menia (southeastern Algeria) to evaluated the effect of two foliar P (agriphos and leader-start) and three soil P (TSP P 46, Fosfacyl NP 3:22 and NPKs 8:36:13,5+15) on yield and P use efficiency of durum wheat crop Triticum durum Desf. var. Carioca and on available P and total P in soil.

Result: Data showed that significant effect of soil P fertilizer on grain yield components (ears m⁻², grains ear⁻¹ and the 1000 grains weight), grain P use efficiency and available P in soil. The best values were recorded by NPKs fertilizer, but no differences were observed for these parameters among foliar fertilizer sources.

Key words: Available P arid land, Durum wheat, Grain yield, P fertilization, P use efficiency.

INTRODUCTION

Phosphorus is one of the most widely occurring nutrients for development and growth of wheat. The problem for this element (P) is its bioavailability, which is essentially controlled by soil pH, slow diffusion and strong adsorption to soil particles (Goos and Johnson, 2001, Pandey et al., 2013). Foliar P fertilization is recommended in dry environments, soils with the elevated P-fixing capacity and soils that are marginally deficient in an effort to avoid pathways that promote loss of soil P (Dhillon et al., 2017). It may be an effective strategy to address the low bioavailability of phosphorus in soil and for the immediate improvement of nutritional stress (Goos and Johnson, 2000; Dixon, 2003; Maltais, 2006; Girma et al., 2007). Several studies have shown that the use of foliar fertilization cannot be an alternative method to root fertilization, but rather complementary (Ling and Silberbush, 2002; Mengel, 2002; Toscano et al., 2002; Pandey et al., 2013).

The addition of fertilizer to the soil is the most common method for supplying minerals to plants. In this case, these elements are absorbed by the roots. However, higher plants can absorb leaf elements when taken at appropriate concentrations (Fageria et al., 2009). So the root is not the only organ that is involved in the absorption of nutrients. The work of Barber (1995), Goos and Johnson (2001) and Pandey et al.(2013) showed that the bioavailability of phosphorus is mainly governed by the pH of the soil solution, its diffusion rate and its strong attachment to soil particles. Therefore, application of foliar-absorbed fertilizers may be an effective strategy to overcome the low bioavailability of phosphorus in soil and for the immediate improvement of nutritional deficit (Goos and Johnson, 2000, Girma et al., 2007). But it can only partially cover insufficient uptake by the roots (Ling and Silberbush, 2002, Pandey et al., 2013).

Laboratory of Saharan Bioresources, University of Kasdi Merbah Ouargla, P.O.Box: 511. 30,000 Algeria.

Corresponding Author: N. Boukhalfa-Deraoui, Laboratory of Saharan Bioresources, University of Kasdi Merbah Ouargla, P.O.Box: 511. 30,000 Algeria. Email: boukhalfan2005@yahoo.fr

How to cite this article: Deraoui, N.B., Mekliche, L.H. and Mekliche, A. (2021). Response of Wheat to Foliar and Soil P Fertilization on Grain Yield and Phosphorus use Efficiency in Southeastern Algeria. Indian Journal of Agricultural Research. 55(1): 99-104. DOI: 10.18805/IJARe.A-576.

Submitted: 01-06-2020 Accepted: 02-08-2020 Online: 29-09-2020

it enhances fertilizer use efficiency and reduced nutrients losses (Qadri et al., 2015).

The acquisition of inorganic nutrients by the roots is interdependent with the assimilation activities at the leaf level. When applied to the foliage, their penetration and uptake into the plant by the different pathways depends mainly on the ionic charge on the plant surface and molecular size (Pandey et al., 2013) and requires a surface sufficient foliar for the foliar fertilizer to become effective (Ling and Silberbush, 2002). Amanullah et al. (2016) reported that foliar fertilizers application is beneficial for improving growth, yield and yield components of field crops under moisture stress condition. The results obtained by Girma et al. (2007) indicated that foliar application improves corn grain and biomass (Zea mays) yields, as well as the efficiency of phosphorus utilization by minimizing the amount of phosphorus brought to the soil by fertilizers. According to Goos and Johnson (2001), early application of foliar phosphorus (4-5-leaf stage

Volume 55 Issue 1 (February 2021)
of wheat) increases phosphorus removal. Other studies by Mosáli et al. (2006) and Al Harby et al. (2013) indicated that a two-node foliar phosphorus spray in winter wheat improves grain yield and phosphorus uptake; while at the heading stage, it provides a better efficiency of use of phosphorus (EUP).

Avila et al. (2012) found that there is no significant difference between the two sources of phosphate (KH$_2$PO$_4$) and phosphate (KH$_3$PO$_4$) foliar fertilizer. Foliar application significantly affected the leaf phosphorus concentration and not the grain yield of the crop compared to the control (Avila et al., 2012; Ali et al., 2014).

Several factors including plant management and environmental factors influence the benefit of foliar P applied (Al-Harby et al., 2013), its effectiveness depends on the soil P fertility, soil moisture status, plant species, chemical form of fertilizer and prevailing climatic conditions (Noack et al., 2010); leaf surface uptake and leaf area available for product interception (McBeath et al., 2015). According to Hu et al. (2008), water stress reduced the absorption of K, Ca, Mg and P elements, which can be attributed to reduced transpiration of maize plants. Phosphorus deficiency can altered the surface structure and function of wheat leaves, which became less permeable to foliar fertilizer (Fernández et al., 2014). According to Ling and Silberbush (2002), the effectiveness of foliar fertilization appears to be limited by the retention capacity of the leaf surface, which has limited the penetration of solutes; the latter can be enhanced by using adjuvant (Noack et al., 2010). Improving nutrient use efficiency is being addressed through implementation of best management practices such as integrated nutrient management planning, improved irrigation scheduling, better application timing and placement and proper fertilizer material selection (Obreza and Sartain, 2010). In the present investigation the objective was to evaluate growth and phosphorus use efficiency by wheat plants fertilized with two foliar Pand three sources of soil pin calcareous-alkaline soil of arid land of Algeria.

MATERIALS AND METHODS

Field trial

The research was investigated in 2006-07 growing season at El-Menia located in Southeastern Algeria, 30°57 N, 2°78 E, latitude and longitude and 397 m above sea level. The region is characterized by an arid climate, therefore very low and erratic rainfall (<100 mm) and warm dry summers with maximum air temperature exceeding 40°C. The main soil characteristics are reported in Table 1.

The experiment was laid out in hierarchical two-factor model design, where, we studied the combined effect of two foliar fertilizers (Agriphos, Leader-start) and three soil P fertilizer (Triple Super Phosphate P 46, Fosfarcy INP 3:22 and NPKs 8:36:13.5+15) on winter wheat (Triticum durum Desf. Var. Carioca).

Crop husbandry

Irrigation

Crop was irrigated with center pivot system and receives an amount of 750 mm water during its growth cycle. Water is pumped from the continental interlayer at 250 m deep, and has a good quality with low salinity risk even for sodicity (Table 2).

Seeds and sowing

For each trait, plants were sown in 1800 m² plots (24×75 m). The seed rate was 200 kg ha⁻¹.

Fertilizer application

Soil P fertilizers were applied at sowing time at level 140 kg P₂O₅ ha⁻¹ commonly used by farmers in the region; while P foliar fertilizers were applied at two stages of wheat, GS 13 and GS 23, according to Zadoks scaling system, 2.5 L ha⁻¹ for each stage. The plots were fertilized with 212 kg N ha⁻¹ as ammonium nitrate and urea (UAN 32), split into several provisions applied by fertigation.

Sampling and plant measurement

All measurements were carried out on five square meters for each treatment. The following yield parameters including the grain yield viz., ears number m⁻², grains number ear⁻¹ and 1000-grain weight were recorded.

The aboveground biomass was determined at three wheat growth stages, second node detectable GS32,
Response of Wheat to Foliar and Soil P Fertilization on Grain Yield and Phosphorus use Efficiency in Southeastern Algeria

flowering GS61 to GS69 and maturity GS91. Samples were analyzed for total P, using colorimetric ascorbic acid method. Phosphorus use efficiency (PUE) was determined at maturity for grain wheat and calculated according to Moll et al. (1982). WHO defined PUE as grain weight (GW) per unit of P available in soil (P soil):

\[ PUE = \frac{GW \text{ (Kg/ha)}}{P_{soil} \text{ (Kg/ha)}} \]

**Statistical analysis**

Experimental data were recorded and classified using Microsoft Office Excel 2010. The significance between the means was determined using analysis of variance (ANOVA) at the level P ≤ 0.05 with the software package Statistica 8.0.

**RESULTS AND DISCUSSION**

**Yield components, Grain yield and aboveground biomass yield**

Data shows a significant effects of soil P fertilizer on number of ears m² (p ≤0.05), the number of grains ear⁻¹ (p ≤0.01) and the 1000-grains weight (p ≤0.001), where, the best values were recorded by NPKs and TSP for ears m², NPKs for number of grains ear⁻¹ and Fosfactyl for the 1000-grains weight; while, the effect on grain yield was not significant (Table 3).

Aboveground biomass yield also showed positive and significant response to P fertilizers soil applied in the three wheat stages, two nodes (p ≤0.01), flowering (p ≤0.05) and maturity (p ≤0.05). NPKs fertilizer promoted greater dry matter accumulation at three wheat stages (Table 4). While, foliar phosphorus application had non-significant effects in all studied traits.

The number of ears m², the number of grains ear⁻¹ and the 1000 grain weight are the main components of wheat grain yield. These traits are genetically controlled and are highly influenced by environmental factors, primarily nutrients available in the soil (Kousar et al., 2015). Grain yield was positively linked to grains number ear⁻¹ (r = 0.25*) and biomass yield at maturity.

Application of soil P with supplement foliar P resulted in a better grain yield in most instances where significant was observed (Al Harby et al., 2013). In previous study (Boukhalfa-Deraouiet et al., 2011), application of 180 kg P₂O₅ ha⁻¹ as TSP fertilizer to soil without foliar P supplement recorded 46 q ha⁻¹ of grain yield, however, in the present study, and for the same fertilizer (TSP) applied at 140 kg P₂O₅ ha⁻¹ with P foliar application, recorded an average grain yield of 50.02 q ha⁻¹, either a difference of 8 per cent (Table 3).

Application of foliar P in early growth stage can increase the number of fertile tillers and crop growth (Grant et al., 2001). Al Harby et al. (2013) reported a significant increase in wheat grain yield was observed with P foliar application at two nodes detectable when compared with flowering stage P application. This response to foliar application will be more in P deficient condition. Similar type of results reported by Rafiullah et al., 2017.

The comparison between the two type of foliar fertilizers viz., Leader-start and Agriphos revealed no significant effect on the improvement of grain yield, biomass and phosphorus uptake by wheat crop. Comparable results are obtained by Ling and Silberbush (2002), which illustrate non-significant differences between the different forms of mineral and organic foliar fertilizer on a maize crop. Corroborating Ling and Silberbush (2002) and the study by Avila et al. (2012) reported that regardless of the foliar fertilizer sources phosphate (KH₂PO₄) or phosphate (KH₂PO₄), common bean growth is not affected.

Rafiullah et al. (2017) in their hydroponic study concluded that P applied as foliar spray up to 144 Mm KH₂PO₄ could be an effective way to enhance the plant growth in P deficient condition and without any detrimental effect on wheat crop. On the other hand, Kaya et al. (2001) found that KH₂PO₄ spraying enhances the negative effects of salt stress on strawberry fruit growth and yield.

**P concentration, P uptake and P use efficiency**

Data on P concentration, P uptake and P use efficiency is furnished in Table 5. The data revealed that P concentration

---

**Table 3: Mean grain yield and yield components under foliar P and soil P applied.**

| Variables       | Ears m² | Grains ear⁻¹ | 1000 GW (g) | Grain yield (q ha⁻¹) |
|-----------------|---------|--------------|-------------|---------------------|
| **Soil P fertilizers** |         |              |             |                     |
| Fosfactyl       | 309.3ᵃ  | 34.55ᵇ       | 50.95ᵃ      | 52.09               |
| TSP             | 343.0ᵃ  | 35.23ᵃᵇ      | 48.43ᵇ      | 50.02               |
| NPKs            | 363.5ᵃ  | 37.13ᵃᵇ      | 49.01ᵇ      | 58.13               |
| *               | *       | **           | ***         | ns                  |
| LSD (5%)        | 31.05   | 2.09         | 1.39        | -                   |
| **Foliar fertilizers** |         |              |             |                     |
| Agriphos        | 336.6   | 35.52        | 49.54       | 51.50               |
| Leader-start    | 340.5   | 35.75        | 49.38       | 55.31               |
| ns              | ns      | ns           | ns          | ns                  |
| General means   | 338.6   | 35.63        | 49.46       | 53.41               |
| CV %            | 20.80   | 13.31        | 6.36        | 25.91               |

ᵃ,ᵇ,ᶜ Significant at P ≤0.05, P ≤0.01 and P ≤0.001, respectively, ns: Not significant, different superscript letters in a column shows significant difference.
and P uptake of shoots are highly affected by soil P fertilizers \((p < 0.001)\), at the two wheat stages viz., two nodes and flowering, where NPKs fertilizer gave the best values.

For the two wheat stages, successively, positive relationships were observed between shoots P content and earsm² \((r = 0.283^*, r = 0.285^*)\) on the one hand and on the other hand with grains numberear² \((r = 0.411^{***}, r = 0.413^{***})\). P uptake was significantly correlated to grains number ear m² \((r = 0.389^{***})\) at flowering stage, and P use efficiency (PUE) was closely related to grain yield \((r = 0.389^{***})\).

Foliar P application enhanced availability of nutrients to crop for obtaining higher yield \((Arif et al., 2006)\). The results obtained by Avila et al. (2012) and Ali et al. (2014) pointed out that the application of foliar fertilizer significantly affected leaf phosphorus concentration and not the grain yield of the crop compared to the control. Ali et al. (2014) showed an 11.6 per cent increase in grain phosphorus concentration relative to the control. According to Dixon (2003), foliar P can increase fertilizer use efficiency. Indeed, Helmy (2013) concluded that spraying

### Table 4: Mean Biomass yield (q ha⁻¹) of wheat at different stages under foliar P and soil P applied.

| Wheat stages | Two nodes | Anthesis | Maturity |
|--------------|-----------|----------|----------|
| Soil P fertilizers |           |          |          |
| Fosfactyl    | 19.4⁵     | 103.0¹   | 108.6²   |
| TSP          | 23.3⁴     | 109.9⁶   | 98.8⁶    |
| NPKs         | 23.7⁴     | 105.9⁶   | 118.9⁷   |
| LSD (5%)     | 2.267     | 6.858    | 10.93    |
| Foliar fertilizers |      |          |          |
| Agriphos     | 22.8⁶     | 107.9⁷   | 106.7⁷   |
| Leader-start | 21.4⁶     | 104.4⁷   | 110.9⁷   |
| General means| 22.1⁶     | 106.2⁷   | 108.8⁷   |
| CV %         | 23.0⁶     | 14.5⁷    | 22.6⁷    |

* *, *** Significant at \(P \leq 0.05, P \leq 0.01, P \leq 0.001\), respectively, ns: Not significant, different superscript letters in a column show significant difference.

### Table 5: Mean wheat P concentration (%DM), P uptake and PUE of wheat grains under foliar P and soil P applied.

| Variables | [P]S1 | [P]S2 | EXP P S1 | EXP P S2 | PUE |
|-----------|-------|-------|----------|----------|-----|
| Soil P fertilizers |       |       |          |          |     |
| Fosfactyl | 0.391⁶ | 0.345⁶ | 7.46⁶ | 36.55⁶ | 64.27 |
| TSP       | 0.563⁵ | 0.485⁵ | 13.0⁵ | 51.16⁵ | 63.49 |
| NPKs      | 0.833⁴ | 0.743⁴ | 19.4⁴ | 79.65⁴ | 73.47 |
| LSD (5%)  | 0.031  | 0.032  | 2.10    | 7.157    |     |
| Foliar fertilizers |       |       |          |          |     |
| Agriphos  | 0.592  | 0.511  | 13.62   | 57.92    | 64.47 |
| Leader start | 0.598  | 0.537  | 12.96   | 53.66    | 69.68 |
| General means | 0.595  | 0.524  | 13.29   | 55.79    | 67.08 |
| CV %      | 8.99   | 10.79  | 27.45   | 22.24    | 35.00 |

* *, **, *** Significant at \(P \leq 0.05, P \leq 0.01, P \leq 0.001\), respectively, ns: Not significant, different superscript letters in a column shows significant difference.

### Table 6: Mean available P and total P under foliar and soil P applied.

| Variables | APS1 | APS2 | APS3 | TPS1 | TPS2 | TPS3 |
|-----------|------|------|------|------|------|------|
| Soil P fertilizers |       |       |       |      |      |      |
| Fosfactyl | 14.2³ | 14.1² | 13.9³ | 36.8⁵ | 36.6⁵ | 36.7³ |
| TSP       | 15.8³ | 16.2³ | 16.1³ | 43.3³ | 43.6³ | 44.2³ |
| NPKs      | 13.4³ | 13.1³ | 13.6³ | 48.8³ | 50.1³ | 48.8³ |
| LSD (5%)  | 1.054 | 1.12  | 1.007 | 3.64 | 3.809 | 3.367 |
| Foliar fertilizers |       |       |       |      |      |      |
| Agriphos  | 14.3⁴ | 14.4⁵ | 14.3⁴ | 42.9⁹ | 43.0⁹ | 43.1⁹ |
| Leader start | 14.6⁵ | 14.5⁶ | 14.8⁴ | 42.9⁹ | 43.8² | 43.3³ |
| General means | 14.5⁰ | 14.5¹ | 14.5⁴ | 42.9⁹ | 43.4¹ | 43.2⁵ |
| CV %      | 12.6  | 13.4  | 11.9  | 14.7 | 15.2 | 13.5 |

AP: available phosphorus, TP: total phosphorus, S1: second node detectable stage, S2: flowering stage, S3: maturity stage. *, **, *** Significant at \(P \leq 0.05, P \leq 0.01, P \leq 0.001\), respectively, ns: Not significant, different superscript letters in a column shows significant difference.
citrin (Fe, Mn and Zn) on common wheat significantly improves phosphorus and nitrogen uptake by grain, resulting in a high PUE compared to unsprayed treatment. Qadri et al. (2015) indicated that foliar application of urea reduces nitrogen losses and increases plant nitrogen use efficiency. Kolota and Osinska (1999) found that foliar application of fertilizer increased marketable yield of field vegetables significantly.

Available phosphorus and total phosphorus in soil

Referring to the results of Table 6, available and total P in soil at different stages (two nodes, flowering and maturity) are significantly (p <0.001) affected by soil P fertilizers. No differences were observed for these parameters among foliar fertilizer sources. The highest contents of available P are obtained by TSP fertilizer (Fig 1) and those of total phosphorus are made by NPKs fertilizer at the three growing stages. On the other hand, the lowest values are obtained by the Fosfacty fertilizer regardless of the stage of sampling. NPKs fertilizer improved in better wheat growth, favoring not only the best grain yield and biomass yield, but also nutrient efficiency.

Available P was negatively correlated to total phosphorus at second node detectable (r = -0.323**), flowering (r = -0.355**) and maturity (r = -0.28*) of wheat. The negative relationship between total phosphorus and available phosphorus could be explained in part by the transfer of phosphorus to non-assimilable forms when the contact time between fertilizer and soil particles increases (Fardeau, 1993, Gao and Grant, 2012).

Phosphorus use efficiency was closely linked to available phosphorus at three wheat stages respectively, r = -0.366**, r = -0.399*** and r = -0.35**.Indeed, total phosphorus in soil influenced significantly P content at second node detectable (r = 0.52*** ) and flowering (r = 0.542***).

The proper fertilizer material selection allows a better efficiency of fertilizer use and result in better growth and yield. In the present study, NPKs fertilizer gave the best results due to its acidifying property.

CONCLUSION

The soils of arid Algerian regions, among them the soil of experimental site are characterized by high content of limestone with an alkaline pH, therefore, the use of foliar-absorbed phosphate fertilizer appears a best management practice and must be integrated into the technical itinerary of cereal crops to improve nutrient uptake through root and decrease the amounts of soil phosphorus fertilizer applied in southeastern Algeria.

REFERENCES

Al Harbi, S.F., Ghoneim, A.M., Modaïlsh, A.S., Mahjoub, M.O. (2013). Effect of foliar and soil application of phosphorus on phosphorus uptake, use efficiency and wheat grain yield in calcareous soil. Journal of Applied Sciences. 13: 188-192.

Ali M.S., Sutradian, A., Edano, M.L., Edwards, J.T., Girma, K. (2014). Response of winter wheat grain yield and phosphorus uptake to foliar phosphate fertilization. International Journal of Agronomy. 10.1155/2014/801626.

Amanullah, Saleem, A., Iqbal, A., Fahad, S. (2016). Foliar phosphorus and zinc application improve growth and productivity of Maize (Zea mays L.) under moisture stress conditions in semi-arid climates. Journal of Microbial and Biochemical Technology. 8: 432-439.

Arif M., Chohan, M.A., Ali, S., Gul, R., Khan, S. (2006). Response of wheat to foliar application of nutrients. Journal of Agricultural and Biological Science. 1(4): 30-34.

Avila, F.W., Faquin, V., Lobato, A.K., Bai, Z., Marques, D.J., Passos, A.M.A., Bastos, C.E.A., Guedes, E.M.S. (2012). Growth, phosphorus status and nutritional aspect in common bean and foliar-applied phosphorous forms. Scientific Research and Essays. 7: 2195-2204.

Barber, S.A. (1995). Soil nutrient bioavailability: A mechanistic approach. Second edition. John Wiley and Sons. 414 pages.

Boukhalfa-Deraoui, N., Halliat, M.T., Mekliche, A. (2011). Effet de la fertilisation phosphatée sur une culture de blé tendre conduite en conditions sahariennes. Revue des Bioressources. 1: 39-46.

Dhilton, J., Torres, G., Driver, E., Figueiredo, B., Raun, W.R. (2017). World phosphorus use efficiency in cereal crops. Soil Fertility and Crop Nutrition. 109: 1670-1677.

Dixon, R.C. (2003). Foliar fertilization improves nutrient use efficiency. Fluid Journal. 11: 11-12.

Fageria, V.D., Filho, M.P.B., Moreira, A., Guimarães, C.M. (2009). Foliar fertilization of crop plants. Journal of Plant Nutrition. 32: 1044-1064.

Fardeau, J.C. (1993). Le devenir du phosphore dans le sol et dans les systèmes sol plante. Perspectives Agricoles. 181:17-22.

Fernández, V., Guzmán, P., Peirce, C., Mcbeath, T.M., Khayet, M., Mclaughlin, M. (2014). Effect of winter wheat phosphorus status on leaf surface properties and permeability to foliar-applied. Plant soil. 384: 7-20.

Gao, X., Grant, C.A. (2012). Cadmium and Zinc Concentration in Grain of Durum Wheat in Relation to Phosphorus Fertilization, Crop Sequence and Tillage Management. Applied and Environmental Soil Science. 10 pages.

Girma, K., Martinim, K.L., Freeman, K.W., Mosali, J., Teal, R.K., Raun, W.R., Moges, S.M., Arnall, D.B. (2007). Determination of optimum rate and growth stage for foliar-applied phosphorus in corn. Communications in Soil Science and Plant Analysis. 38: 1137-1154.
Goos, R.J. and Johnson, B.E. (2000). A comparison of three methods for reducing iron deficiency chlorosis in soybean. Agronomy Journal. 92 (2): 1135-1139.

Goos, R.J. and Johnson, B.E. (2001). Response of spring wheat to phosphorus and sulphur starter fertilizers of differing acidification potential. Journal of Agricultural Science. 136: 283-289.

Grant, C.A., Flaten, D.N., Tomasiewiecz, D.J. (2001). The importance of early season phosphorus nutrition. Canadian Journal of Plant Science. 81: 211-224.

Helmy, A.M. (2013). Impact of phosphorus fertilization and foliar application of trace elements on growth and yield of two wheat cultivars. Acta Agronomica Hungarica. 61 (2): 139-148.

Hu Y., Burcs, Z., Schmidhalter, U. (2008). Effect of foliar fertilization application on the growth and mineral nutrient content of maize seedlings under drought and salinity. Soil Science and Plant Nutrition. 54(1): 133-141.

Kaya, C., Kirnak, H., Higgs, D. (2001). An experiment to investigate the ameliorative effects of foliar potassium phosphate sprays on salt-stressed strawberry plants. Australian Journal of Agricultural Research. 52(10): 995-1000.

Kolota, E., Osinska, M. (1999). Efficiency of foliar nutrition of field vegetables grown at different nitrogen rates. Proceedings of the international conference on environmental problems associated with nitrogen fertilization of field grown vegetable crops, Potsdam, 30 August-1 September 1999, 87-91.

Kousar, P., Ali, L., Raza, A., Maqbool, A., Maqbool, S., Rasheed, S., Irun, N. (2015). Effect of different levels of nitrogen on the economic yield of Wheat (Triticum aestivum L.) variety Aas-11. International Journal of Agronomy and Agricultural Research. 6 (3): 7-11.

Ling, F., Silberbush, M. (2002). Response of maize to foliar vs. soil application of nitrogen-phosphorus-potassium fertilizers. Journal of Plant Nutrition. 25(11): 2333-2342.

Mallarino, A.P., Mazhar, U., Wittry, D., Bermudez, M. (2001). Variation of Soybean response to early season foliar fertilization among and within fields. Agronomy Journal. 93 (6): 1220-1226.

Maltais, A.M. (2006). Facteurs et conditions favorables à l'efficacité de la fertilisation foliaire des cultures maraichères du Québec. Revue de littérature, Faculté des sciences de l'agriculture et de l'alimentation. Département de phytologie, U. Laval. 21p.

McBeath, T., Facelli, E., Peirce, C., Mcmaughlin, M., Hunt, E. (2015). “Topping Up” wheat with foliar P- Does it work? GRDC Adelaide adviser updates: GRDC-ORM Communications; 2015. SCIRO/ EP15289.

Mengel, K. (2002). Alternative or complementary role of foliar supply in mineral nutrition. Acta Horticulturae. 594: 33-47.

Moll, R.H., Kamprath, E.J., Jackson, W.A. (1982). Analysis and interpretation of factors which contribute to efficiency of nitrogen utilization. Agronomy Journal. 74: 562-564.

Mosali, J., Girma, K., Teal, R.K., Freeman, K.W., Martin, K.L., Raun, W.R. (2006). Effect of foliar application of phosphorus on winter wheat grain yield, phosphorus uptake and use efficiency. Journal of Plant Nutrition. 29(12): 2147-2163.

Noack, S.R., Mcebeat, T.M., Mclauhln, M.J. (2010). Potential for foliar fertilization of dryland cereal crops: a review. Crop Pasture Science. 61(8): 659-669.

Obreza, T.A., Sartain, J.B. (2010). Improving nitrogen and phosphorus use efficiency for Florida's horticultural crops. Hor Technology. 20(1): 23-33.

Obreza, T.A., Sartain, J.B. (2010). Improving nitrogen and phosphorus use efficiency for Florida's horticultural crops. Hor Technology. 20(1): 23-33.

Pandey, R., Krishnapiiya, V., Bindraban, P.S. (2013). Biochemical nutrient pathways in plants applied as foliar spray: phosphorus and iron. Virtual Fertilizer Research Center Report USA. 16 pages.

Qadri, R.W.K., Khan, I., Jahangir, M.M., Ashraf, U., Samin, G., Anwer, A., Adnan, M., Bashir, M. (2015). Phosphorous and foliar applied nitrogen improved productivity and quality of potato. American Journal of Plant Sciences. 6: 144-149.

Rafiuilah Khan, M.J., Muhammad. D. (2017). Foliar application of phosphorus to enhance phosphorus utilization and crop growth: a hydroponic study. Sarhad Journal of Agriculture. 34(1): 47-53.

Samad, A., Muhammad, D., Musarat, M., Ullah, W. (2014). Enhancing wheat yield and phosphorus use efficiency through foliar application in calcareous soil. Journal of Natural Sciences Research. 4(7): 70-74.

Toscano, P., Godino, T., Belfiore, Bricelli-Bati, C. (2002). Foliar fertilization: a valid alternative for olive cultivar. Acta Horticulturae. 594: 191-195.