# Strategies of Growing Several Sorghum Cultivars as a Post-Harvest Crop in North-Eastern Croatia Condition

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# Strategies of Growing several Sorghum Cultivars as a Post-Harvest Crop in North-Eastern Croatia Condition

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**Summary**

Recent climate changes lead toward possibility of using longer period of higher temperatures after winter crops harvest for establishing post-harvest crop, such is sorghum. It can produce significant biomass, useful both for feed and bioenergy, even in drier summers, with reduced soil tillage preparation. The trial was set up in Poljanci, Croatia, in years 2015 and 2016 as a split-plot design with foliar fertilizers and sorghum cultivars treatments, established by diskharrowing soil after winter wheat harvest in mid-July, and harvested before autumn frosts at the end of November. Foliar fertilizers treatments were C) Control (no fertilization), B) Biological (Condi agro) and M) Mineral (EcoTop Folimax) foliar fertilizers. Cultivars used in trial were KSH3723, KSH3724, Lemnos, Leonie, Merlin, Sammos, Santos, Sole, Tarzan and Zerberus. Foliar fertilizer treatments B and M showed higher dried biomass yield for 7 and 11% in comparison with C, respectively. Difference between treatments were higher at fresh biomass yield. Treatments B and M showed 12 and 22% higher fresh biomass yield than C, respectively. Regarding the tested sorghum cultivars, the highest fresh biomass yield was recorded for Leonie (32933 kg ha$^{-1}$), followed by Lemnos (27467 kg ha$^{-1}$) and KSH3724 (26600 kg ha$^{-1}$), whereas the lowest yield was recorded for Zerberus (19600 kg ha$^{-1}$).

**Key words**

sorghum, post-harvest crop, foliar fertilizers

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## Introduction

Usually, high yields in modern agriculture are possible due to genetic potential of crops and applied crop growing technics, were fertilization ads up to 50% of crop yield (Stewart et al., 2005). Nitrogen is one of the most important nutrient used in agricultural systems and contributes strongly to the sustainability, resilience, economical performance, and improvement of cropping systems (Delgado and Shaffer, 2008); however, nitrogen use efficiency is usually reported to be lower than 50% (Newbould, 1989) and the losses of added nitrogen fertilizers can be very significant (Wu et al., 2005). Today, the imperative is to continue the development, estimation, and adoption of new management practices that increase nitrogen recovery and reduce potential losses to the environment (Delgado and Shaffer, 2008). One of the potential solutions which may contribute to reducing environmental pollution by excess nitrogen from fertilizers is foliar fertilizers application, since the total amount of applied nutrients is significantly lower, with higher utilization ratio (Kettlewell and Juggins, 1992). Use of the combined NPK foliar fertilizer for different crops is more common (Kannan, 2006), but results are not always positive (Haq and Mallarino, 2000) so there is a need for further research to determine actual effectiveness. Another way to reduce the nitrogen leaching is the introduction of summer catch crops in crop rotation in the period between winter and summer cash crops. Summer crops can be used for food production, fodder, green manure and bio-energy (Kemp, 2011), thus ensuring extra profit, contribute to sustainability, resilience and also to diversification of both, production and market. Furthermore, grown as a post-harvest crop, they can utilize nitrogen, which remained after the main crop was harvested (Lochart and Wiseman, 1983), and thus reduce leaching and prolong the cycle of circulation of nitrogen in the soil. Summer catch crops are usually grown in unfavorable weather conditions (summer spell or summer precipitation deficiency) in which usual technology based on moldboard ploughing and mineral granular fertilizer incorporation in soil often does not result with positive effects. In recent years, many investigations showed the need for climate change mitigation in certain aspects of crop production (Bayhan at al., 2006, Kovačević et al., 2007, Birkas et al. 2008, Stipešević et al., 2011). Sorghum (*Sorghum bicolor*) is one of the potentially utilizable crops for that role, especially due its drought resilience (Cattivelli et al. 2008), with also long history of breeding for that trait (Rosenow et al. 1983). However, the biggest problem is to find the best suitable cultivar for given environment and role in crop rotation. Therefore, the aim of this study was to determine effects of different cultivars and foliar side-dressing cropping systems for sorghum sown as post-harvest crop.

## Materials and methods

The field experiment was carried out on the Family Agricultural Enterprise (FAE) “Stipešević Ivica” near Poljanci, Croatia, during the summers of 2015 and 2016. The soil type was the eutric cambisol, with favorable crop production properties. The climate is moderate subhumid continental type. The preceding crops in both years was winter barley (*Hordeum sativum* L.). In both years, the agrotechniques for preceding crops included soil preparation by conventional tillage, based on autumn moldboard ploughing before fine seedbed preparation by disk harrowing and seedbed cultivator and usually recommended fertilization for both crops (120 kg N, 100 kg P and 120 kg K per ha). Soil tillage preparation for sorghum was single passage by heavy disk harrow up to 15-20 cm, followed by seedbed preparation cultivator, with coarse seedbed preparation and over 50% of soil surface covered by previous crop’s residues. Pre-seeding fertilization was omitted for post-harvest sown sorghum. The seeding was performed with available cereal seeders at the row distance of 30 cm, depth of 2-3 cm and targeting seeding density of 30-35 grains $m^{-2}$. In year 2015 seeding had been performed in the second week of July, and in year 2016 in the first week of July. The experiments in both years were set up as the split-plot design in four repetitions, with ten levels of sorghum cultivars and three sub-levels of side-dressing, with basic experimental plot size for side-dressing of 2 m x 5 m. The sorghum (*Sorghum bicolor*) cultivars used in trial in both years were: KSH3723, KSH3724, Lemnos, Leonie, Merlin, Sammos, Santos, Sole, Tarzan and Zerberus. Used foliar fertilization sub-treatments were: C) no-side-dressing control; B) Biological foliar fertilizer (Condi agro), with several aerobic and anaerobic microorganisms, including bacteria, actinomycetes, yeasts and mildews, in rate of 7 l $ha^{-1}$ in two sprayings; and M) Mineral foliar fertilizer (EcoTop Folimax) which contains both macro (N, P, K, Ca) and micro (B, Cu, Fe, Mn, Mo and Zn) nutrients, in rate of 5 l $ha^{-1}$ in two sprayings. Side-dressings were performed 4 and 6 weeks after the seeding in each year. Harvests were performed manually in the last week of October 2015 and first week of November 2016. Harvested sorghum biomass was weighted and sub-sampled. Plant sub-samples were dried up at 60°C and than weight for moisture content estimation. The statistical analysis of the variance (ANOVA) of experiment was performed by SAS statistic package (V 9.1, SAS Institute, Cary, NC, USA, 1999). The Fisher protected LSD means comparisons were performed for P=0.05 significance levels for year, cultivar, side-dressing and their interactions.

The weather during both seasons is presented by Table 1. The summer 2015 was hot, with unequal and unusual precipitation pattern; July was very dry, August and September had normal

**Table 1.** Weather conditions in summer 2015 and 2016, weather station Slavonski Brod, Croatia

| | | July | August | September | October | | |
|---|---|---|---|---|---|---|---|
| T (°C) | 2015 | 24,9 | 23,5 | 17,6 | 11,4 | Means | 19,4 |
| | 2016 | 23,1 | 20,3 | 17,2 | 10,2 | | 17,7 |
| P (mm) | 2015 | 15 | 79 | 71 | 144 | Sums | 309 |
| | 2016 | 141 | 28 | 67 | 64 | | 300 |

precipitation level, whereas October was extremely wet. On the other hand, the summer 2016 was slightly less hot, with very wet July, dry August, normal September and October.

## Results and discussion

The highest sorghum fresh biomass yield in 2015 was achieved by cultivar Leonie (Table 2) with average of 38 t ha$^{-1}$ of biomass, which was not significantly higher than following cultivar Sole, with 25.9 t ha$^{-1}$ of biomass. Statistically lower than Leonie, but at the same level of significance, were cultivars Merlin, Santos, KSH 3724, Tarzan and Lemnos, with yields ranging from 24.1 to 22.9 t ha$^{-1}$ of biomass. The lowest yield in 2015 had cultivar Sammos, with only 17.4 t ha$^{-1}$ of biomass. Dried biomass yield (Table 3) showed similar sequence of yields for cultivars, with cultivar Leonie being with the highest yield (8.8 t ha$^{-1}$ of dry biomass), followed by cultivar Sole (6.8 t ha$^{-1}$ of dry biomass) and finishing with cultivar Sammos being with the lowest yield (only 3.6 t ha$^{-1}$ of dry biomass). Cultivar Lemnos was with the highest fresh biomass yield in 2016 (Table 2) and with 32 t ha$^{-1}$ of biomass it was significantly better than following cultivar KSH 3724, which yielded 29.6 t ha$^{-1}$ of biomass. Following cultivars Sammos, KSH 3723 and Leonie had yield from 29.3 to 27.9 t ha$^{-1}$ of biomass. The lowest biomass yield in 2016 was recorded for cultivar Sole, with only 19.5 t ha$^{-1}$. Dry biomass yield (Table 3) had similar sequence of yields for named cultivars. Cultivar Lemnos recorded 8 t ha$^{-1}$ of dry biomass, significantly better than following cultivar KSH 3724 (7.2 t ha$^{-1}$ of dry biomass). Cultivars KSH 3723, Leonie, Santos and Sammos produced significantly lower dry biomass yields, ranging from 6.6 to 6.1 t t ha$^{-1}$. The lowest dry biomass yield was recorded for cultivar Sole, with only 5.1 t t ha$^{-1}$. In average of both years, cultivar Leonie was with the highest biomass yield of 32.9 t ha$^{-1}$ (7.6 t ha$^{-1}$ of dry biomass). Following cultivar Lemnos had significantly lower biomass yield of 27.5 t ha$^{-1}$ (6.9 t ha$^{-1}$ of dry biomass). Significantly lower biomass yielded cultivars KSH 3724 and Santos, with biomass yields of 26.6 and 23.4 t ha$^{-1}$ (6.4 and 6.2 t ha$^{-1}$ of dry biomass), respectively. Following cultivars had below 25 t ha$^{-1}$ of biomass (6 t ha$^{-1}$ of dry biomass), whereas the lowest yield was recorded for cultivar Zerberus, with only 19.6 t ha$^{-1}$ (5.3 t ha$^{-1}$ of dry biomass). Differences among cultivar's performances in different growing seasons (2015 being more dry and warmer at the beginning than 2016) can be partially be explained with differences in rooting depth, where same cultivar can have deeper rooting in drier environment, thus reacting better in rest of the season through adaptation of rooting and internal xylem structure, as described by Salih et al. (1999). Also, special emphasis in modern cultivar selection, such as KSH 3723 and KSH 3724, is given to "stay green" effect, where "stay green" materials tend to root deeper than senescent cultivars (Vadez et al., 2007), thus adopting better to harsher environments.

In both years, both B and M foliar fertilizers produced additional biomass of all sorghum cultivars in comparison with control treatment, but without statistical significance. However, trends shows 13% higher fresh biomass yields with B foliar treatment (ranging from 5 to 31% higher yields in comparison with control) and 22% higher fresh biomass yields with M foliar treatment (ranging from 13 to 35% higher yields in comparison with control). Positive effects of foliar fertilization has been presented by different authors (Wittwer and Teubner, 1959; Be and Scagel, 2007; Fernandez and Eichert, 2009), especially for plants in early development, due to better foliar absorption rates of younger leaves. Giskin and Efron (1986) also found higher silage yield of maize with foliar fertilizers. Foliar fertilization with organic components and growth stimulators gave higher leaf yield and more aromatic compounds of *Mentha piperita var. citrata* (Hendawy et al., 2015) through better physiological processes in plant, which corroborate to results of applying B foliar treatment. However, Hu et al. (2008), found no higher maize growth, but, they contributed lack of foliar fertilization to maize growth to soil saline conditions.

Also, it is interesting to point out that differences between biomass yields as result of applied B and M foliar treatments were 9%, but, only five cultivars had additional yield higher than 10% with M treatment in comparison with B treatment, where 10% is arbitrary level of treatment's differentiation. This finding may indicate

**Table 2.** Average fresh biomass yield (kg ha$^{-1}$) of sorghum cultivars and applied foliar treatments, Poljanci site, years 2015 and 2016

| Cultivar | Control | Condi Agro | EcoTop Folimax | Cultivar mean | Rank |
|---|---|---|---|---|---|
| | | Year 2015 | | | |
| KSH 3723 | 17200 | 20800 | 25600 | 21200 c | 8 |
| KSH 3724 | 22800 | 23600 | 24400 | 23600 b | 4 |
| Lemnos | 22400 | 23000 | 23400 | 22933 b | 7 |
| Leonie | 35400 | 38800 | 39800 | 38000 a | 1 |
| Merlin | 23600 | 24800 | 24000 | 24133 b | 3 |
| Sammos | 16800 | 18000 | 17400 | 17400 d | 10 |
| Santos | 20800 | 22400 | 27600 | 23600 b | 4 |
| Sole | 25600 | 26400 | 25800 | 25933 ab | 2 |
| Tarzan | 20800 | 26000 | 22800 | 23200 b | 6 |
| Zerberus | 16000 | 19600 | 19200 | 18267 d | 9 |
| Foliar mean | 22140 a | 24340 a | 25000 a | 23827 y | |
| | | Year 2016 | | | |
| KSH 3723 | 25200 | 28400 | 31600 | 28400 bcd | 4 |
| KSH 3724 | 27200 | 29600 | 32000 | 29600 b | 2 |
| Lemnos | 28000 | 30000 | 38000 | 32000 a | 1 |
| Leonie | 24800 | 26000 | 32800 | 27867 cd | 5 |
| Merlin | 20400 | 27200 | 27600 | 25067 e | 7 |
| Sammos | 26400 | 30000 | 31600 | 29333 bc | 3 |
| Santos | 24800 | 26800 | 30000 | 27200 d | 6 |
| Sole | 14400 | 20400 | 23600 | 19467 g | 10 |
| Tarzan | 17200 | 23600 | 25600 | 22133 f | 8 |
| Zerberus | 18800 | 19200 | 24800 | 20933 g | 9 |
| Foliar mean | 22720 a | 26120 a | 29760 a | 26200 y | |
| | | Both years mean | | | |
| KSH 3723 | 21200 | 24600 | 28600 | 24800 de | 5 |
| KSH 3724 | 25000 | 26600 | 28200 | 26600 bc | 3 |
| Lemnos | 25200 | 26500 | 30700 | 27467 b | 2 |
| Leonie | 30100 | 32400 | 36300 | 32933 a | 1 |
| Merlin | 22000 | 26000 | 25800 | 24600 de | 6 |
| Sammos | 21600 | 24000 | 24500 | 23367 ef | 7 |
| Santos | 22800 | 24600 | 28800 | 25400 cd | 4 |
| Sole | 20000 | 23400 | 24700 | 22700 f | 8 |
| Tarzan | 19000 | 24800 | 24200 | 22667 f | 9 |
| Zerberus | 17400 | 19400 | 22000 | 19600 g | 10 |
| Foliar mean | 22430 a | 25230 a | 27380 a | 25013 | |

Means labeled with the same lowercase letter for same Cultivar or Foliar side-dressing average in each Year or Means group are not statistically different at P>0.05 significance level.

**Table 3.** Average dry biomass yield (kg ha$^{-1}$) of sorghum cultivars and applied foliar treatments, Poljanci site, years 2015 and 2016

| Cultivar | Control | Condi Agro | EcoTop Folimax | Cultivar mean | Rank |
|---|---|---|---|---|---|
| | | Year 2015 | | | |
| KSH 3723 | 3970 | 4801 | 5909 | 5355 ef | 8 |
| KSH 3724 | 5959 | 5764 | 5568 | 5666 e | 6 |
| Lemnos | 5899 | 5798 | 5646 | 5722 de | 5 |
| Leonie | 8049 | 8822 | 9049 | 8822 a | 1 |
| Merlin | 5555 | 5740 | 5463 | 5601 e | 7 |
| Sammos | 3631 | 3756 | 3506 | 3631 g | 10 |
| Santos | 5017 | 6182 | 4659 | 6182 cd | 4 |
| Sole | 6784 | 6942 | 6732 | 6837 b | 2 |
| Tarzan | 6118 | 5581 | 6976 | 6225 c | 3 |
| Zerberus | 5233 | 5342 | 4361 | 4851 f | 9 |
| Foliar mean | 5621 a | 5873 a | 5787 a | 5889 y | |
| | | Year 2016 | | | |
| KSH 3723 | 5817 | 6556 | 7295 | 6556 c | 3 |
| KSH 3724 | 7109 | 7229 | 7303 | 7214 b | 2 |
| Lemnos | 7373 | 7562 | 9169 | 8035 a | 1 |
| Leonie | 5639 | 5912 | 7458 | 6336 cd | 4 |
| Merlin | 4802 | 6296 | 6282 | 5793 e | 8 |
| Sammos | 5706 | 6260 | 6367 | 6111 cde | 6 |
| Santos | 5982 | 7396 | 5064 | 6147 cde | 5 |
| Sole | 3816 | 5364 | 6158 | 5113 f | 10 |
| Tarzan | 5059 | 5066 | 7833 | 5986 de | 7 |
| Zerberus | 6149 | 5233 | 5633 | 5672 e | 9 |
| Foliar mean | 5745 a | 6287 a | 6856 a | 6296 y | |
| | | Both years mean | | | |
| KSH 3723 | 4894 | 5679 | 6602 | 5956 cde | 7 |
| KSH 3724 | 6534 | 6496 | 6436 | 6440 bc | 3 |
| Lemnos | 6636 | 6680 | 7408 | 6878 b | 2 |
| Leonie | 6844 | 7367 | 8254 | 7579 a | 1 |
| Merlin | 5179 | 6018 | 5872 | 5697 def | 8 |
| Sammos | 4668 | 5008 | 4936 | 4871 g | 10 |
| Santos | 5499 | 6789 | 4861 | 6164 cd | 4 |
| Sole | 5300 | 6153 | 6445 | 5975 cde | 6 |
| Tarzan | 5588 | 5323 | 7405 | 6105 cd | 5 |
| Zerberus | 5691 | 5288 | 4997 | 5262 fg | 9 |
| Foliar mean | 5683 a | 6080 a | 6322 a | 6093 | |

Means labeled with the same lowercase letter for same Cultivar or Foliar side-dressing average in each Year or Means group are not statistically different at P>0.05 significance level.

differences of leaf structure or potential benefit from foliar uptake of organic growth stimulators in comparison with pure mineral fertilization, where organic growth stimulators are not present. In case of post-sown millet, buckwheat and sudan grass, Stipešević et al. (2010, 2011) found that biological foliar fertilization can be as effective as foliar fertilizers with mineral nutrients only. Ling and Silberbush (2002) also found no significant difference among different foliar fertilizers on maize growth.

Regarding the average of both years, there were no statistical differences of fresh and dry biomass between them, presumably that, in spite of slightly higher temperature for 2015, seemingly more favorable distribution of precipitation in 2016 provided a slightly higher biomass average.

## Conclusion

The present study of the effects of sorghum cultivars and foliar side-dressing systems on post-harvest sown sorghum in Northeastern Croatia agro-environment showed that the highest biomass yield can be obtained with cultivar Leonie, followed by Lemnos, KSH 3724, Santos, KSH 3723, Merlin, Sammos, Sole, Tarzan and Zerberus. Foliar side-dressing with used liquid fertilizers showed relative trend of higher yields for all cultivars in comparison with cropping sorghum as post-harvest crop without any side-dressing. In more cases mineral foliar fertilizer showed trend of contributing toward higher biomass yield of sorghum than used biological foliar fertilizer.

## References

Bayhan, Y. Kayisoglu, B. Gonulol, E. Yalcin, H., Sungur, N. (2006). Possibilities of direct drilling and reduced tillage in second crop silage corn. Soil and Tillage Research 88: 1-7.

Bi, G., Scagel, C. (2007). Nitrogen foliar feeding has advantages. Nurs. Manage Prod. 23(3):43–46.

Birkas M., Kisić I., Stipešević B., Javurek M., Vach M. (2008). Climate change – a subsequent challenge to abandon the conventional tillage ideas in Central Europe. Proceedings of 5th International Soil Conference: Soil Tillage - New Perspectives, Brno, Czech Republic: 283-292.

Cattivelli L., Rizza F., Badeck F.W., Mazzucotelli E., Mastrangelo A.M., Francia E., Marè C., Tondelli A., Stanca, A.M. (2008). Drought tolerance improvement in crop plants: an integrated view from breeding to genomics. Field Crops Research, 105/1-2: 1-14.

Delgado, J., A., M. Shaffer. (2008). Nitrogen Management Modeling Techniques. Assessing Cropping Systems/Landscape Combinations. Nitrogen in the Environment: Sources, Problems, and management, Second edition, ed. J. L. Hatfield & R. F. Follett (Amsterdam, Boston, et al.: Academic Press/Elsevier, 2008): 539-570.

Fernández, V., Eichert, T. (2009). Uptake of hydrophilic solutes through plant leaves: current state of knowledge and perspectives of foliar fertilization. Crit. Rev. Plant. Sci. 28: 36–68.

Giskin M., Efron Y. (1986). Planting date and foliar fertilization of corn grown for silage and grain under limited moisture. Agron. J., 78: 426–429.

Hendawy S.F., Hussein M.S., El-Gohary A.E., Ibrahim M.E. (2015). Effect of Foliar Organic Fertilization on the Growth, Yield and Oil Content of Mentha piperita var. citrate. Asian Journal of Agricultural Research, 9/5: 237-248.

Hu Y., Burucs 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.

Kannan S. (2010). Foliar fertilization for sustainable crop production. In Genetic Engineering, Biofertilisation, Soil Quality and Organic Farming, Sustainable Agriculture Reviews 4. Ed. Lichtfouse E., Springer: 371-402.

Kemp L. (2011). Second harvest: bioenergy from cover crop biomass. Natural Resources Defence Council: 1-30.

Kettlewell P.S., Juggins S.A. (1992). Can foliar application of nitrogen fertilizer to winter wheat reduce nitrate leaching? Aspects Appl. Biol. 30: 103-108.

Kovačević, D., Oljača, S., Denčić, S., Kobiljski, B., Dolijanović, Ž. (2007). Održiva poljoprivreda-značaj adaptacije agrotehničkih mera u proizvodnji ozime pšenice. Journal of Scientific Agricultural Research, 68: 39-50.

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.

Lochart J.A.R., Wiseman A.J.L. (1983). Introduction to crop husbandry (including grassland). Pergamon Press: 111-115.

Newbould, P. (1989). The use of nitrogen in agriculture: Where do we go practically and ecologically? Plant Soil 115: 297-311.

Rosenow D.T., Quisenberry J.E., Wendt C.W., Clark L.E. (1983). Drought tolerant sorghum and cotton germplasm. Agri. Water Management, 7/1-3: 207-222.

Salih A.A., Ali I.A., Lux A., Luxova M., Cohen Y., Sugimoto Y., Inanga S. (1999). Rooting, water uptake, and xylem structure adaptation to drought of two sorghum cultivars. Crop Sci. 39: 168-173.

Stewart W.M., Dibb D.W., Johnston A.F., Smyth T.J. (2005). The Contribution of Commercial Fertilizer Nutrients to Food Production. Agron. J. 97/1: 1-6.

Stipešević, B., Brozović, B., Jug, D., Stošić, M., Jug, I., Vukadinović, V., Simić, M., Mladenović-Drinić, S., Toth, B., Levai, L. (2010). The influence of soil tillage system at germination of buckwheat, millet and sudan grass sown as post-harvest summer crops. Proceedings of CROSTRO Conference "Soil tillage-Open approach", Osijek, Croatia, 09-11 September, 2010: 137-141.

Stipešević B., Brozović B., Jug D., Stošić M., Levai L. (2011). The influence of different soil tillage and top dressing management on post-harvest sown millet. Novenytermeles, 60: 187-190.

Vadez V., Krishnamurthy L., Kashiwagi J., Kholova J., Devi J.M., Sharma K.K., Bhatnagar-Mathur P., Hoisington D.A., Hash C.T., Bidinger F.R., Keatinge J.D.H. (2007). Exploiting the functionality of root systems for dry, saline, and nutrient deficient environments in a changing climate. SAT eJournal/ejournal.icrisat.org, 4/1: 1-55.

Wittwer S.H., Teubner, F.G. (1959). Foliar absorption of mineral nutrients. Annual Review of Plant Physiology, 10: 13–32.

Wu L., Letey J., French C., Wood Y., Bikie D. (2005). Nitrate leaching hazard index developed for irrigated agriculture. J. Soil Water Conservation, 60: 90-95.

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