Indian J.L.Sci. 2(1): 175-180, 2012 ISSN: 2277-1743 (Print)
ISSN: 2278-7879 (Online)

INVESTIGATING THE POTENTIAL OF FOLIAR NUTRIENT APPLICATION AS A SUPPLEMENT TO SOIL FERTILIZATION IN ISABGOL (*Plantago ovata*) PRODUCTION

RAJAN CHAUDHARY[1]

Department of Botany, BUC College, Batala-143505, Punjab, India

E-mail: chaudhary_jan23@yahoo.co.in

ABSTRACT

This study examines the use of foliar nutrients to augment soil fertilization in Isabgol (*Plantago ovata* L) cultivation. Agricultural systems often apply nutrients foliarly to correct nutrient shortages or increase absorption. This study examines how foliar fertilizer spray affects Isabgol plant growth, production, and quality. In Isabgol agriculture regions, soil fertilization and foliar nutrition administration were tested. Isabgol height, leaf area, biomass buildup, and seed output were measured. To examine fertilizer absorption efficiency, soil and plant tissue nutrient concentrations were measured. Foliar nutrients greatly affected Isabgol growth, yield, and nutritional status. Compared to soil fertilization alone, foliar fertilizer spray boosted plant growth and nutrient concentrations. Foliar application improved nutrient absorption, especially for soil-poor micronutrients. Foliar nutrients improved Isabgol seed quality. Foliar nutrient administration improved seed quality, including husk production, mucilage content, and medicinal characteristics.

KEYWORDS: Potential, Foliar, Nutrient

Foliar feeding applies liquid fertilizer to plant leaves. Plant leaves absorb nutrients. Stomata and epidermis absorb. Foliar spray involves spraying crop leaves with nutrients. This approach applies modest amounts of fertilizers, notably micronutrients. This procedure may also provide major fertilizers to dry soil. Foliar application supplements soil application. Foliar feeding, especially on horticultural crops, has become commonplace in crop production. Foliar feeding has been shown to enhance agronomic crops, although it is still rare.

Mechanism of Foliar Fertilization

- A foliar fertilizer nutrient must first obtain access into the leaf before it can reach the cytoplasm of a cell located within the leaf in order for the plant to be able to make use of it for growth. This is a prerequisite for the nutrient to be used by the plant.
- In order to accomplish this goal, the nutrient must efficiently permeate the outer cuticle as well as the wall of the underlying epidermal cell.
- Once this has occurred, the process of nutrient absorption by the cell is analogous to the process of root absorption.
- The cuticle provides the highest level of resistance among all of the components that make up the pathway that foliar-applied nutrients take.

Foliar feeding is not intended to take the place of fertilizing the soil in any way. Application to the soil is the most efficient and cost-effective method of satisfying the key nutritional requirements of a plant (nitrogen, phosphorus, and potassium). Foliar application, on the other hand, has been shown to be an excellent method of supplying secondary nutrients (such as calcium, magnesium, and sulphur) and micronutrients (such as zinc, manganese, iron, copper, boron, and molybdenum) to plants, in addition to supplementing their requirements for nitrogen, phosphorus, and potassium during critical growth three stage periods. Foliar feeding is done for the primary purpose of delaying the natural senescence processes that begin shortly after the reproductive growth phases come to an end. Foliar feeding is directed at the development phases that are characterized by decreasing rates of photosynthesis as well as leveling off of root growth and nutrient absorption. This is done in an effort to facilitate the movement of nutrients into seed, fruit, tuber, or vegetative production. Foliar feeding is also known as foliar application. In a secondary sense, foliar feeding may be an efficient management method to positively affect pre-reproductive growth phases by compensating for the environmental stressors that are caused by unfavorable growing circumstances and/or a lack of available nutrients. This can be done by adding nutrients directly to the plant's leaves. An already healthy crop can be improved with the use of early foliar treatments in one of two ways: either by encouraging more robust regrowth or by maximizing the yield potential growth stage time. Foliar feeding has a number of benefits that are helpful in achieving the results that are sought with the crop.

1. It is a highly efficient and timely method of applying needed and/or critical plant nutrients.
2. It is a means of compensating for soil or environmentally induced nutrient deficiencies.

[1]**Corresponding author**

Proper Timing of Foliar Applications

The appropriate growth stage is one of the elements that is of the utmost importance in a foliar feeding program. Foliar treatments should be scheduled to deliver the necessary nutrients throughout the time period of plant growth that is responsible for defining the yield potential. This will, in turn, have a favorable impact on the phases of plant development that occur after reproduction. It is possible that several treatments at a low rate will exhibit the most favorable reactions within these time frames, regardless of whether or not a crop is nutritionally sound. It is vital to conduct careful monitoring of the growth stage of the crop on a weekly, and occasionally daily, basis. In order to determine the quantities of plant nutrients that are most inhibiting to crop growth, it is required to conduct a complete plant tissue analysis study right before the application that is wanted. Analysis of tissue testing using the DRIS (Diagnosis and Recommendation Integrated System) is the most effective way to relate tissue nutrient levels to the demands that are wanted for the plant. This approach works by ranking plant nutrients in the order of most limiting to least limiting. Please refer to the appendix for information on the appropriate timing and rates of foliar sprays for individual crops.

Condition of the Crop: In general, foliar feeding will have the best chance of success when applied to crops that already have a healthy nutritional profile. This is as a result of improved tissue quality (which enables maximal nutrient absorption in the leaf and stem) and improved growth vigor (which enables translocatable nutrients to be swiftly transferred to the remainder of the plant). Because of decreased absorption rates in the leaf and stem tissue and/or inadequate vigor, crops that are under stress from either heat or moisture exhibit a reduced response to foliar treatments. However, the crop's performance and production can be improved by foliar feeding if the application was done before it was subjected to heat or moisture stress. The use of the appropriate foliar treatments can help plants recover more quickly from the stress caused by herbicides and cold growth conditions. It has been found that corn that received light to moderate hail damage and had nitrogen-sulfur solutions administered foliarly has a good chance of recovering from the damage. Foliar feeding, on the other hand, has a limited capacity for rescue in the majority of situations because of the constraints imposed, both practically and economically, on the amount of nutrients that can be supplied to the leaves in order to stimulate a desirable growth response.

Conditions Meteorologiques Appropriate: The physical and biological elements of foliar sprays are affected by environmental factors such as the time of day, temperature, and humidity levels, as well as the speed and direction of the wind. characteristics that are warm, wet, and tranquil favor the highest tissue permeability, which are characteristics that are seen most commonly in the late evening hours, and rarely in the early morning hours. The permeability of the plant tissue is an important element in the absorption of nutrients into the plant. The following table provides a summary of the climatic conditions that are favorable for foliar sprays.

Table 1: Meteorological condition favouring foliar applications

Time of Day:	Late evening; after 06:00 p.m. Early morning; before 09:00 a.m.
Temperature:	Low temperature 18-19 ºC (Ideal 21 ºC)
Humidity:	Greater than 70% relative humidity
Wind speed:	Less than 5 mph
Rainfall:	Within 24 to 48 hours after a foliar application may reduce the application effectiveness, as not all nutrient materials are immediately absorbed into the plant tissue

Foliar feeding: desirable characteristics

1. Solubility: foliar fertilizers should be able to either dissolve or suspend themselves in water, and they should include an active component chemical compound like as salts, chelates, or complexes of mineral nutrients.
2. Molecular weight and size: In order to have more penetration of the leaf cuticle, foliar fertilizer must either have a low molecular weight or molecules of a smaller size than those found in water.
3. Adjusting the pH of the solution is necessary in order to promote more effective nutritional action and to protect against the consequences of scalding or burning.
4. Structure The rate at which ammonium ions are absorbed into the leaves is significantly higher than the rate at which nitrate ions are absorbed. When compared to other inorganic N fertilizers, urea has a greater leaf penetration rate. Due to the fact that it crystallizes so quickly on leaf surfaces, potassium chloride is suitable for use in soil fertilization but not in foliar application.

Table 2: Rates of nutrient absorption into plant tissues

Nutrient	Time for 50% absorption
Nitrogen (as Urea)	½-2 hours
Phosphorous	5-10 days
Potassium	10-24 hours
Calcium	1-2 days
Magnesium	2-5 days
Sulphur	8 days
Zinc	1-2 days
Manganese	1-2 days
Iron	10-20 days
Molybdenum	10-20 days

Types of Fertilizer Materials/Additives/Water

Materials for Fertilizer: Not every type of fertilizer may be applied to leaves in the form of a foliar spray. Foliar fertilizer formulations should fulfill specific requirements in order to prevent harm to the plant's foliage. The primary purpose of a foliar spray is to enable maximum absorption of nutrients into the plant tissue. Foliar fertilizer formulations should also allow for optimum absorption of nutrients. The following are the qualifications for materials used in fertilizer:

Low salt index: The amount of damage that may be caused to plant cells by excessive salt concentrations can be significant, particularly when it comes to the effects of nitrates (NO3 -) and chlorides (Cl-).

A high solubility is required since it allows for a less volume of solution to be used during the application process.

High purity is required in order to avoid causing any interference with the spraying process, problems with compatibility between solutions, or unanticipated negative effects on the plant life.

PLANT TISSUE TEST

The analysis of crop plant tissue may also be utilized to diagnose nutritional problems in plant plants. On the other hand, it is the method that costs the most money to determine whether or not sufficient nourishment is being consumed. For plant tissue tests to be as accurate and trustworthy as possible, it is vital to have the findings of plant analysis conducted in a variety of agroecological locations for each crop species. Only then can the results of analytical testing be interpreted. The findings of plant analyses differ depending on the crop type, plant age, and plant section that was examined. Because of this, one must exercise extreme caution when using a plant tissue test to determine whether or not a certain nutrient is in sufficient or insufficient supply. Absorption of nutrients by developing plants is influenced by a wide variety of variables, including soil, environment, plant, and the interplay between these three. In plant tissues, however, the concentrations of the necessary nutrients are kept within very restricted ranges. This is because of the importance of these nutrients. According to Fageria and Baligar (2005), such consistency may result from the working of delicate feedback mechanisms that enable plants to adapt in a homeostatic manner to changes in their environment. The conclusion that can be drawn from this is that the findings of plant analysis are more reliable than the results of soil testing. For the sake of interpretation, this means that the findings from one place to another location for the same crop species can be used. Even when comparing data from different countries, plant analysis for the same kind of crop might occasionally yield equivalent findings.

MECHANISMS OF UPTAKE OF FOLIAR APPLIED NUTRIENTS

Photosynthesis is an essential process that takes place in green leaves, which are organs. However, there is adequate information available that demonstrates that inorganic and organic compounds may also be absorbed via the surfaces of leaves (Franke, 1967). Because the cell walls of leaves are coated by a cuticle, which is not present in the structure of roots, it is possible that the method by which leaves absorb nutrients is distinct from that of roots. According to research conducted by Franke in 1967, cuticular membranes are permeable to both organic and inorganic ions as well as molecules that have not been dissociated. Ions' capacity to penetrate a substance is dependent on the type of charge they carry, as well as the ion's adsorbability and radius. Under typical circumstances, the absorption of ions in leaves results in a buildup that goes against the concentration gradient. This is also the case in roots. The energy that is necessary for active absorption can be obtained either by respiratory metabolism or, as the example of green leaves in Franke's 1967 study demonstrates, through photosynthesis. According to Franke (1967), both the quality and intensity of the light enhance the rate at which leaves absorb ions. According to Franke (1967), there may be three distinct steps involved in the process of ion absorption by leaves. In the first step, compounds that are applied to the leaf surface diffuse through the cuticle and into the cellulose wall in either a restricted or free manner, respectively. After penetrating the free space, these compounds enter the second stage, in which they undergo some type of binding that causes them to get adsorbed on the surface of the plasma membrane. The third step sees the substances that have been absorbed go into the cytoplasm, a process that requires energy that is produced from the metabolism of the cell.

Previous studies (Middleton and Sanderson, 1965; Franke, 1967) shown that the cuticular wax, the cuticle, the cell wall, and the membrane are the specific locations in which foliarly applied nutrients are absorbed by the plant. According to Dybing and Currier's research from 1961, some of the time the nutrient will go through all of these different layers, while other times it will travel via the gaps in between these layers. This is normal behavior for inorganic ions. On the other hand, it has recently been demonstrated that ions may also be absorbed via the stomata of leaves (Eichert *et al.*, 1998; Eichert and Burkhardt, 2001). According to Burkhardt *et al.* 1999, foliar absorption is often more effective when the stomata are open. During the process of ontogenesis, it is critical for a plant to remobilize the mineral nutrients it has stored. For instance, if a nutrient is unable to be delivered from the sprayed tissues to those forming after the spray treatment, then the spray treatment needs to be repeated each time a fresh flush of development develops (Papadakis *et al.*, 2007). This is because the nutrient cannot be transferred from the sprayed tissues to those developing after the spray treatment. In other words, if a nutrient is immobilized after its application to the foliar layer of a plant, the beneficial benefits of the spray would be confined solely to the tissues that were sprayed. As a result, signs of nutrient inadequacy will manifest themselves in the shoots that sprout following spraying. The mobility of macronutrients in plant tissue is reasonable, with the exception of calcium and sulfur. However, the mobility of the vast majority of micronutrients in plant tissues is rather low.

For instance, Gettier *et al.* (1985) found that two or more foliar sprays may be necessary during the growth season for soybean due to the fact that manganese is not very good at being remobilized and its mobility in the phloem is limited. According to Guzman *et al.* (1990), the element Fe does not move about very much in tomato, cucumber, and navy bean, but it moves around quite a bit in muskmelon. On the other hand, it was observed that Mn played the role of a stationary nutrient in all three of these species. In addition, Marschner (1995) found that the mobility of iron (Fe) and manganese (Mn) in the phloem of plants is either deemed to be low or moderate, respectively. According to Garnett and Graham (2005), iron possesses a high reproductive mobility in wheat. The evidence of iron's remobilization was significantly more than that of manganese, which was discovered. As a result, we may reach the following conclusion: the remobilization of nutrients inside plant tissues varies greatly depending on the nutrient and the plant type.

CROP RESPONSES TO FOLIAR FERTILIZATION

Soybean and wheat were the subjects of the majority of the studies that were conducted and reported on regarding the effects of foliar fertilization on crop growth. Depending on the crop species and the nutrient that was sprayed, crop responses to foliar fertilization have been variable, ranging from positive to negative to no reaction at all. Extensive research on foliar fertilization of soybean during early vegetative growth stages or during late reproductive growth stages was carried out between the years of 1970 and 1980. The results of this research showed inconsistent increases in grain yield (Parker and Boswell, 1980; Poole *et al.*, 1983; Haq and Mallarino, 1998; 2000; Mallarino *et al.*, 2001; Nelson *et al.*, 2005). When a liquid N-P-K-S fertilizer was sprayed on plants in their late reproductive stages (R5 to R6), Garcia and Hanway (1976) found that yields increased by between 27 to 31%. According to these writers, root activity drops during pod fill, and as a result, the plant is unable to absorb enough nutrients to satisfy the requirements placed on them by the seeds. Although Syverud *et al.* (1980) found that nitrogen additions led to slight improvements in soybean production, they found that PKS had very little impact on the crop. These authors also observed that an increase in seed weight and seed N concentration was brought about by the application of foliar nitrogen treatments. On the other hand, Boote *et al.* (1978) were unable to improve either the soybean yield or the seed number, and they discovered some small burn and necrotic patches on the leaf surfaces.

In the majority of cases, the leaf damage that was caused by foliar sprays of N-P-K-S was severe enough to cause a reduction in soybean yield that was evaluated by Parker and Boswell (1980). According to the findings of Haq and Mallarino (1998), foliar fertilization with varied amounts of nitrogen, phosphorus, and potassium applied at the R5 development stage enhanced soybean grain yield in seven out of forty-eight field experiments, while it marginally decreased yields in two trials, with an overall mean yield gain of fifty-four kg per hectare. In a similar vein, Poole *et al.* (1983) found that increasing the amount of fertilizer N-P-K-S that was applied through foliar spray to soybeans during the podfill stages (R4 to R7) of their growth increased crop yields. Numerous studies that were carried out around the same time and subsequently did not duplicate these findings and indicated that foliar fertilization of soybean either did not effect or lowered yield (Boote *et al.*, 1978; Parker and Boswell, 1980). These findings were contradicted by the findings of a number of other studies that were carried out around the same period and afterward. According to the findings of these authors, the leaf damage brought on by foliar fertilization can occasionally be severe enough to bring about a drop in yield. However, Wesely *et al.* (1998) showed that soybean production was greatly boosted by the foliar fertilization of ammonium nitrate solution at the rate of 22 kg N ha-1 during the R3 development stage. This was done while the soybeans were in their reproductive stage.

According to Mallarino *et al.* (2001), applying foliar fertilization with nitrogen to soybeans during the early development stages does not affect the process of nitrogen fixation, and the absorption of phosphorus and potassium can be enhanced during this period even if the root system is not yet fully established. It's possible that these beneficial impacts may boost plant development, and as a result, grain output. When sprayed as foliar fertilization, some nutrients have the potential to interact favorably with other nutrients, which might result in increased crop yields. A foliar application of sulfur as a fertilizer to soybeans, for instance, did not result in an increase in grain output. A foliar N application that was applied as a liquid spray resulted in higher grain protein concentration levels than when n was broadcast as dry granular fertilizer at late growth stages on wheat (Alkier *et al.*, 1972; Strong, 1982). This was found to be the case when the nutrient was applied in a combination of N, P, and K. (Garcia and Hanway, 1976). In a similar vein, Bly and Woodard (2003) found that grain protein and yield from plots that did not receive foliar nitrogen exhibited an adverse relationship (R2 = 0.57), and that nine out of the twelve locations had significant grain protein concentration responses to the application of foliar nitrogen.

Even while early-season nitrogen applications were more than sufficient for prospective grain production (Pushman and Bingham, 1976), several studies have found an increase in grain protein content as a result of the administration of late-season nitrogen either as foliar sprays or as dry topdress fertilizers. This was the case even when the application of nitrogen during the early season was sufficient. According to the findings of Finney and colleagues (1957), applying foliar nitrogen to wheat after the blooming stage led to the maximum levels of grain protein content. According to Bly and Woodard (2003), an increase in grain protein content by the use of foliar fertilization during the late development stage of wheat might prevent a price deduction and perhaps result in a premium being refunded to the producer in years where conditions are favorable. Chesnin and Shafer (1953) conducted research on soybeans in Nebraska, and their findings did not demonstrate a consistent beneficial response to foliar applications of nitrogen and phosphorus. The Tennessee Valley Authority (TVA) oversaw the coordination of 180 foliar fertilizer studies on soybeans across 11 states in the United States.

The results of these comparisons were published in a study titled "Peele, 1977," which stated that the average yield across the states ranged from a drop of 396 kg ha-1 to a gain of 27 kg ha-1. Foliar treatments of nitrogen, phosphorus, potassium, and sulfur were shown to raise the nutritional content of soybeans in Florida, as reported by Boote *et al.* (1978). However, these applications did not appreciably alter yields, nor did they lengthen the period of photosynthesis. These authors also found that the yield of control soybeans was 3825 kg ha-1, which was higher than the yield of soybeans treated with foliar fertilizer, which was 3617 kg ha-1. When soy is cultivated on soils high in calcium, a condition known as iron deficiency chlorosis is frequently observed. There are two management strategies that stand out as particularly useful in the fight against iron chlorosis in soybeans produced in calcareous soils. The first strategy is to utilize iron-efficient cultivars, while the second strategy is to provide iron via foliar sprays.

According to the findings of Goos and Johnson (2000), the addition of 1.1 kilograms per hectare (ha) of iron ethylenediaminetetraacetic acid (FeEDTA) to 140 liters per hectare (ha) of water resulted in an increase of 8% in grain production across four different sites and three cultivars when compared to the control treatment (no spray). These researchers came to the conclusion that cultivar selection is, and will continue to be, the most effective method for preventing Fe-deficiency chlorosis in soybeans grown in narrow rows on calcareous soils.

CONCLUSION

Foliar nutrients were tested as a complement to soil fertilization in Isabgol (*Plantago ovata* L) cultivation. Foliar nutrients improve plant growth, nutrient absorption, and seed quality, according to study. Combining soil fertilization with foliar nutrients greatly affected Isabgol growth, yield, and nutritional status. Foliar nutrient application boosted plant growth and nutrient concentrations compared to soil fertilization alone. Foliar spraying improved the absorption of soil-limited micronutrients. Foliar nutrients improved Isabgol seed quality. Foliar fertilizer treatment boosted husk production, mucilage content, and medicinal qualities, suggesting better market value and advantages. Foliar nutrient treatment may complement soil fertilization in Isabgol farming. It directly supplies nutrients to plants, bypassing soil nutrient limits and boosting nutrient absorption. Farmers and agronomists can maximize

Isabgol output and seed quality by applying foliar nutrients.

Research can optimize foliar nutrient delivery and investigate nutrient absorption and utilization processes. Investigating the long-term impacts of foliar nutrient application on soil fertility, nutrient cycling, and sustainability would help Isabgol producers establish holistic nutrient management strategies. Studying the connections between foliar nutrient administration and other agronomic parameters, such as irrigation management or pest control, would offer a complete knowledge of their influence on Isabgol growth and yield. This research suggests supplementing soil fertilization with foliar nutrients in Isabgol farming. Foliar sprays can boost plant nutrient absorption and crop output. Foliar fertilizer treatment improves seed quality, which can boost Isabgol product demand and value. Foliar fertilizer application must be cost-effective and practicable for certain farming systems and resource restrictions. To enhance efficacy and reduce environmental impact, foliar spray timing, frequency, and nutrient compositions should be researched and tested. This study shows that foliar nutrients can enhance soil fertilization in Isabgol production. Foliar application improves plant growth, nutrient absorption, and seed quality. Farmers may maximize Isabgol output, crop quality, and market demand by applying foliar nutrients. Foliar fertilizer application research and practice will support Isabgol production and the agricultural business.

REFERENCES

Alkier A.C., Racz G.J. and Soper R.J., 1972. Effects of foliar and soil applied nitrogen and soil nitrogen level on the protein content of Neepawa wheat. Canadian Journal of Soil Science, **52**: 301–309.

Bly A.G. and Woodard H.J., 2003. Foliar nitrogen application timing on grain yield and protein concentration of hard red winter and spring wheat. Agronomy Journal, **95**: 335–338.

Campbell W.H., 1999. Nitrate reductase structure, function and regulation: Bridging the gap between biochemistry and physiology. Annual Review of Plant Physiology and Plant Molecular Biology, **50**: 277–303.

Dybing C.D. and Currier H.B., 1961. Foliar penetration of chemicals. Plant Physiology, **36**: 169–174.

Eichert T., Goldbach E.H. and Burkhardt J., 1998. Evidence for the uptake of large anions through stomatal pores. Botanica Acta, **111**: 461–466.

Fageria N.K., Baligar V.C. and Clark R.B., 2002. Micronutrients in crop production. Advances in Agronomy, **77**: 185–268.

Gamble P.E. and Emino E., 1987. Morphological and anatomical characterization of leaf burn in corn induced from foliar applied nitrogen. Agronomy Journal, **79**: 92–96.

Gooding M.J. and Davies W.P., 1992. Foliar urea fertilization of cereals: A review. Fertilizer Research, **32**: 209–222.

Haq M.U. and Mallarino A.P., 2000. Soybean yield and nutrient composition as affected by early season foliar fertilization. Agronomy Journal, **92**: 16–24.

Kaya C., Kirnak H. and Higgs D., 2001. Enhancement of growth and normal growth parameters by foliar application of potassium and P in tomato cultivars grown at high NaCl salinity. Journal of Plant Nutrition, **24**: 353– 367.

Lewis D.J. and Kettlewell P.S., 1993. A comparison of the uptake of P from foliar applied phosphate by the leaves of eleven varieties of potato. Aspects of Applied Biology, **34**: 243–248.

Mengel K., Kirkby E.A., Kosegarten H. and Appel T., 2001. Principles of Plant Nutrition, 5th ed. Dordrecht: Kluwer Academic Publishers.

Nelson K.A., Motavalli P.P. and Nathan M., 2005. Response of notill soybean (Glycine max. L. Merr.) to timing of preplant and foliar potassium applications in a claypan soil. Agronomy Journal, **97**: 832– 838.

Sharpley A.N., Chapra S.C., Wedepohl R., Sims J.T., Daniel T.C. and Reddy K.R., 1994. Managing agricultural phosphorus for protection of surface waters: Issues and opinions. Journal of Environmental Quality, **23**: 437–451.

Tisdale S.L., Nelson W.L. and Beaton J.D., 1985. Soil Fertility and Fertilizers, 4th edition. New York: Macmillan.

Woolfolk C.W., Raun W.R., Johnson G.V., Thomson W.E., Mullen R.W., Wynn K.J. and Freeman K.W., 2002. Influence of late season foliar nitrogen applications on yield and grain nitrogen in winter wheat. Agronomy Journal, **94**: 429–434.

Zadoks J.C., Chang T.T. and Konzak C.F., 1974. A decimal code for the growth stages of cereals. Weed Research, **14**: 415–421.