NITROGEN METERING IN DRY CULTIVATION AND IN FERTIGATION

DOTT. VINCENZO TUGNOLI – DOTT. GIOVANNI BETTINI

Sugarbeet Grower Association (Associazione Nazionale Bieticoltori) – Technical Service
Via Collamarini 14 - Italy – 40138 Bologna

ABSTRACT

The years of experience ANB has acquired in nitrogen metering in sugar beet cultivation both experimental and more recently in the open field have made it possible to improve both production and quality. Autumn and winter soil testing enables one to determine the necessary nitrogen content before sowing. Subsequent checking of the cultivation (4-6 true leaves) with the N-tester allows one to fine-tune fertilization coverage, advising different treatments for each individual area of cultivation. The results of 9 years of ANB experiments adopting such metering in dry crops indicate a 17% increase in production (sugar content) as compared to unfertilized crops and an 8% increase over those fertilized in the traditional manner; the quality of the dense juice (DJP) appeared on the average 2% higher than obtained with crops more heavily fertilized but not using the metering method. When low-volume drip or microirrigation systems are available, it is possible to apply nitrogen throughout the various stages of plant development, when the crop needs it the most. ANB tests, performed since 1999, indicate that the nitrogen doses can be reduced by as much as 20%. The sugar yields were more significant: in Northern Italy there was a 40-50% increase in the southern Po River Valley and 20-30% in the northern Po area; in central Italy the increase was more than 100% over crops obtained with traditional dry crop fertilizer application. Recently large-scale use of these methods in the open-field are producing encouraging results both regarding means of administration and quantities obtained. Further tests conducted by ANB since 1990 have shown that mineral nitrogen is best applied with the sowing of radishes and mustard in the autumn (prior to sowing sugar beets in the spring) in rows set 45 cm apart (so that in the spring sugar beets or another crop can be sown between the rows, the advantage of this is improved soil health and fertility). These plants have a significant biocide effect on nematodes. Moreover, thanks to their particular ability to store nitrogen, they prevent the leaching of nitrogen and enhance soil fertility.

ABRÉGÉ

Les expériences pluriannuelles d'ANB sur des apports guidés de l'azote dans la culture de la betterave, aussi bien au niveau expérimental que, dernièrement, en plein champ, permettent d'améliorer la production et la qualité. Les contrôles effectués en automne et en hiver sur les contenus dans le sol ont pour but de déterminer l'apport d'azote nécessaire avant la semence, et les contrôles

successifs sur la culture en cours (4-6 vraies feuilles) avec N-tester permettent d'affiner la fertilisation de couverture avec des conseils différenciés dans les différentes zones de culture. Les résultats expérimentaux obtenus par ANB en 9 ans d'activité indiquent, grâce à l'adoption de ce système d'administration guidée en culture sèche, des valorisations productives (saccharose) de 17% par rapport au sol non fumé et de 8% par rapport à des dosages traditionnels ; la qualité de la pulpe dense (PSD) est en moyenne supérieure de 2% par rapport à des fumages plus abondants administrés sans l'utilisation de méthodes guidées. Grâce à l'irrigation à bas volumes avec des systèmes goutte à goutte ou des micro-asperseurs, il est possible de distribuer l'azote dans les différentes phases de développement, lorsque la culture en a le plus besoin ; les expériences d'ANB, réalisées à partir de 1999, indiquent la possibilité de réduire la dose d'azote de 20%. Les rendements en saccharose sont plus significatifs avec une valorisation au Nord (zone Sud du Pô) de 40-50% et de 20-30% dans la zone Nord du Pô, tandis qu'au Centre de l'Italie elle atteint plus de 100% par rapport aux apports traditionnels sur la culture en sec. La récente application en plein champ à grande échelle de ces indications donne actuellement des résultats flatteurs aussi bien en ce qui concerne les modalités d'administration que les quantités. D'autres essais réalisés par ANB dès 1990 démontrent la possibilité d'une meilleure gestion de l'azote minéral par la semence de raifort ou de moutarde en automne (en précession à la betterave) selon des rangées espacées de 45 cm (pour permettre la semence interligne successive au printemps ou la semence d'une autre espèce printanière, tout à l'avantage d'une amélioration de la santé et de la fertilité du sol). Ces plantes ont par ailleurs une forte action biocide à l'égard des nématodes, elles empêchent la lixiviation de l'azote, grâce à leur action particulière qui consiste à le stocker, et favorisent la fertilité.

KURFASSUNG

Langjährige Erfahrungen von ANB auf dem Gebiet der gesteuerten Zuführungen von Stickstoff beim Rübenanbau ermöglichen es, sowohl auf experimentellem Niveau als auch – seit kurzem – auf freiem Feld, eine Verbesserung der Produktion und der Qualität zu erlangen. Die Herbst- und Winterkontrollen hinsichtlich der Erdbodenbeschaffenheit werden zu dem Zweck ausgeführt, die erforderliche Stickstoffzuführung vor der Aussaat zu individualisieren, während die daran anschließenden Kontrollen der sprießenden Kultur (4 – 6 wirkliche Blätter) mit N-Tester die Möglichkeit geben, die Deckungsdüngung mit differenzierten Ratschlägen in den verschiedenen Anbaugebieten zu optimieren. Die von ANB in neun Jahren der Aktivität erlangten experimentellen Resultate zeigen bei Anwendung dieses Systems einer gesteuerten Zuführung bei trockenem Anbau Produktionswertsteigerungen (Saccherose) von 17% im Vergleich zu den nicht gedüngten und von 8% im Vergleich zu den herkömmlichen Dosierungen an; die Qualität des dickflüssigen Saftes (PSD) ist durchschnittlich um 2% höher erschienen im Vergleich zu reichhaltigeren Düngungen, die ohne die Anwendung von gesteuerten Zuführungsmethoden erfolgt waren. Bei Vorhandensein einer Bewässerung mit niedrigem Volumendurchfluss mit Tropfanlagen oder mit Mikrobewässerungsapparaten ist es möglich, den Stickstoff in den verschiedenen Entwicklungsphasen zu verteilen, wenn der Anbau ihn dringender benötigt; die von ANB seit dem Jahr

1999 gemachten Erfahrungen geben Hinweis auf die Möglichkeit, die Stickstoffdosierung um 20% zu verringern. Die Ergiebigkeiten von Saccharose resultierten bedeutender mit einer Wertsteigerung im Norden (im südlichen Pogebiet) von 40 – 50% und im nördlichen Pogebiet von 20 – 30%, während diese Wertsteigerung in Mittelitalien mit über 100% im Vergleich zu den herkömmlichen Zuführungen bei trockenem Anbau angezeigt wurde. Die kürzlich erfolgte Anwendung dieser Hinweise auf freiem Feld auf weitläufiger Basis zeigt vielversprechende Resultate, sowohl in Bezug auf die Modalitäten der Zuführung als auch auf die Quantitäten. Weitere von ANB seit 1990 ausgeführte Versuche zeigen die Möglichkeit einer besseren Gestion des Mineralstickstoffs mit der Rettich- oder Senfaussaat im Herbst (vor der Zuckerrübe), in 45 cm voneinander entfernten Reihen (zur Ermöglichung der daran anschließenden Frühjahrsaussaat der Zuckerrübe oder einer anderen Frühjahrsart in den Zwischenräumen, was den Vorteil einer Verbesserung der Güte und der Fruchtbarkeit des Bodens zur Folge hat). Diese Pflanzen führen darüber hinaus eine starke Biozidaktion gegen die Nematoden (Fadenwürmer) aus, verhindern dank der besonderen Stickstoffspeicherung die Auslaugung des Stickstoffs und fördern die Fruchtbarkeit.

INTRODUCTION

Fertilization plays a primary role in all agricultural cultivation and is even more important for sugar beets, particularly in Italy. Sugar beets are, in fact, more sensitive to nutrient deficiencies or excesses, particularly given its economic importance in crop rotation. Because of its high production costs, sugar beet cultivation also requires particular attention to prevent compromising the bottom line. ANB has performed statistical studies over several years at Italian sugar beet farms and has shown that fertilization accounts for 15% of the production costs in Northern Italy and 18% in the South. It, therefore, goes without saying that rational cultivation techniques are essential to reducing production costs. Cultivation errors can no longer be accepted as they cut into agricultural profitability.

Rational application of techniques appears to be the only way to counteract the inclement weather and soil conditions so typical of the Mediterranean environments and is even more imperative in the cultivation of sugar beets. Identification of the times, means and doses to be used to integrate any deficiencies that arise during the crop cycle is of utmost importance. This enables the plant to pursue normal photosynthesis, allowing it to fully ripen which is of both agricultural and industrial interest.

Particular attention must be focused on nitrogen. Both excess nitrogen and nitrogen deficits can penalize production and quality. For a more rational fertilization, the most avant-garde technologies available must be exploited to prevent the onset of abnormal element absorption by the plants. The objective is to enable well-balanced growth, without inducing plant stress. To prevent both nutrient deficiencies and excesses, the amounts to be administered, particularly of nitrogen, must be determined taking into consideration the actual soil contents. In Italian environments, insufficient administration leads to reduced beet growth while a surplus interferes with polarimetric values and a continuous

supply of nutrients causes renewed vegetation which can be economically detrimental.

THE ANB TECHNIQUE FOR NITROGEN METERING

Chemical analysis of soil samples performed in the laboratory in the summer-autumn and repeated in the winter provides information on the real nutrient content in the soil. This, in turn, permits rational management of the quantities to be administered before cultivation, at the time the fields are sown. Besides determining the presence of stabile elements such as phosphorous and potassium, chemical soil analysis can also evaluate the supply of nitrogen. Indeed, nitrogen is essential to plant physiology as it facilitates chlorophyll photosynthesis, plant development and the accumulation of sugar. Since it is a mobile element, plants display a lack of nitrogen with widespread yellowing, in particular following abundant, prolonged rains. This is particularly true in light, organic substance deprived soils. Likewise, poorly structured terrain (subsequent to work at depths of less than 50 cm, wet soils or soils with an inadequate water content) and the particularly clayey soils (with a clay content of more than 40%), typical of Italian sugar beet cultivation, reduce the absorption of the elements administered, thus accentuating the nutritional deficiencies. Of equal importance is an excessive administration of nitrogen. The plant is stimulated to continue revegetating and this consumes sugar and is thus detrimental to the beet polarimetry when delivered to the sugar factory.

It is therefore understandable that both cases result in economic losses for the farmer and have a negative effect on the entire sugar industry, from farm to factory. For this reason it is absolutely essential to determine the exact amount of nitrogen to be administered to crop starting from information on what is already present in the field. Only starting out intelligently can we best meter out the applications required and reach positive results in line with those achieved in other European countries.

Once the initial amounts have been determined, it is important to proceed rationally during the following phases of cultivation. For a rational fertilization management, the Associazione Nazionale Bieticoltori (National Sugar Beet Growers Association) Technical Service has set up a detection system to be used while crops are in the field. With the aid of an optical instrument (N-Tester), this system can evaluate the plant cover requirements. Through nearly ten years of experimental study conducted on various terrains and with different nitrogen supplies, ANB has worked up a correlation between the foliar reading index identified in the field and the nitrogen doses to be administered.

EXPERIMENTAL TESTING

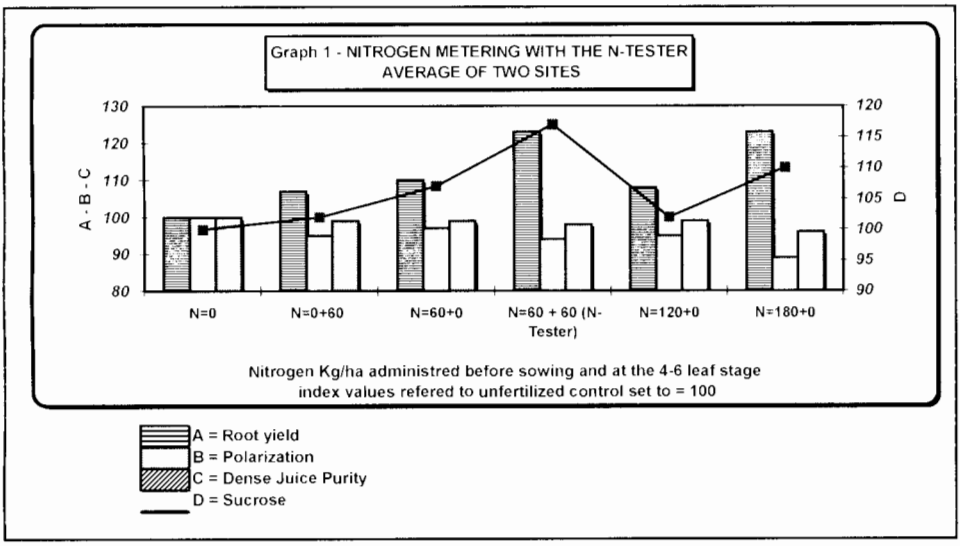
In order to carefully evaluate the function of this optical instrument, the ANB Testing Center, recognized by the Ministry of Agriculture in 1999, performed on dry and irrigated crops to study different levels of nitrogen application.

TESTS ON DRY CROPS

Materials and methods – 6 randomized replicates of 6 different nitrogen treatments applied in plots with the following per hectare units of nitrogen, applied prior to sowing + coverage at the 4-6 leaf stage: 1) 0+0; 2) 0+60; 3) 60+0; 4) 60+N-Tester determination (indicating a requirement of 60 units); 5) 120+0; 6) 180+0.

Results – Graph 1 reports the average production and quality results from the two above-illustrated experimental fields. The results obtained show an increase in beet yield as the level of nitrogen administration increases, reaching the best values at the doses of 60 + 60 (determined with the N-Tester) and 180 units/ha. These results were statistically different from the other test results with an increase of 23% over the unfertilized control. Moreover the fertilized plots showed a statistically significant decrease in polarization vs. the control. The test with 180 units of N/ha, administered prior to sowing, were the worst with an 11% decrease in polarization; the other fertilized tests showed a decrease of between 3 and 6%. The DJP quality (dense juice purity) was slightly lower than in the control with values varying between 1 and 2%. Only the test with 180 N units presented a significant drop of 4%, a statistically significant difference from the other tests. As regards sugar content, the 60 + 60 N-Tester application gave the maximum, statistically significant increase of 17% over the control and 10% over the test with 60 units applied prior to sowing.

The test demonstrated that nitrogen metering with a preliminary analysis to valuate the nutrient element levels presenting the soil and the successive use of the N-Tester can be performed in the 4-6 leaf stage of sugar beet cultivation using the method ANB has set up over seven years of testing. Moreover, with this metering method the plant is not subjected to distress, a plus for natural beet development.



TESTS ON CROPS TREATED WITH FERTIGATION

The ANB irrigation technique using hose or drip line not only to provides a limited, low volume water supply over brief periods of time (little and often) but also promptly supplies the fertilizing elements the crop needs at the moment of greatest absorption. This prevents waste of water and fertilizers and can reduce the quantities of elements administered, in particular nitrogen (-20/30%). In fact, nitrogen is a tricky fertilizer for sugar beets as a lack of this element can have negative consequences on production while an excess is detrimental to polarization. Specific tests performed by the ANB Technical Service highlight the validity of this water-fertilizers combination (+8-10%); increases in sugar content have also been recorded under conditions where the land is worked less (+32%). Fertigation through micro-drip irrigation (+6-8%) has also proved valid on production. This technique is beginning to take hold on farms in Northern and Central Italy; the increased production in the field is on the order of 20-30% while the dense juice purity is the same or better than in crops irrigated in the traditional manner with the hose reel. Thus we can conclude that the initial expense for the purchase and management of such drip systems is fully repaid by greater crop profitability, achieved through the supply of water and better management of nitrogen fertilization. The present work reports an experimental test performed with two different irrigation systems with and without fertigation.

FERTIGATION TESTS WITH HOSE AND MINI-IRRIGATORS

Materials and methods - The tests were performed in Tuscany, in the Chiana River Valley in the Province of Arezzo at the ARSIA farm owned by the Region and in Northern of Italy, at Consandolo, in the Province of Ferrara. The test was performed on land with the following characteristics: sand 34%, silt 36%, clay 30%, pH 7.42, total lime 21.1%, active lime 11.5%, organic substance 0.5, N 0.7‰, P_2O_5 37 ppm, exchangeable potassium K_2O 124 ppm, MgO 230 ppm, CaO 3256 ppm, cationic exchange capacity 18 meq/100g, Mn 4.6 ppm, B 0.25 ppm, C/N 7.2.

The test was set using the "strip test" experimental method to compare the following 6 treatment hypotheses:

Drip irrigation system with hose: a drip micro-irrigation system with hose perforated at 30 cm intervals, hole thickness 8 mill and operating pressure of 0.8 bar. The hoses were positioned every other row of sugar beets; that is, 90 cm apart. The test called for sectors irrigated with fertigation, both with and without the addition of microelements, and others using conventional fertilization with granular products.

Sprinkler irrigation system: a 170 l/h capacity sprinkler system with an operating pressure of 2.5-3 bar. The system set the sprinklers in an 8 x 8 m triangle. As above, the test called for sectors irrigated with fertigation, both with and without the addition of microelements, and others using conventional fertilization with granular products.

Irrigation method: the ARSIA water balance method was used to determine the

irrigation intervals and volumes of water. This method applies the Hargreaves formula and considers 75% recovery of evapotranspiration.

During the irrigation season, 4 operations were performed. For the hoses this involved a total of 1063 m^3 of water per hectare and 1138 m^3 for the sprinklers. For each of the two irrigation systems, the following treatments were performed: 1) conventional nitrogen fertilization with 80 units of N prior to sowing + 40 units of N applied on the ground with granular fertilizers (confirmed with N-Tester); 2) 60 units of N prior to sowing + 25 units of N with fertigation (30% less N than in test 1); 3) 60 units of N prior to sowing + 25 units of N plus the microelements B and Mn with fertigation (30% less N than in test 1). A single beet extirpation was performed. For test 3, evaluation of the nitrogen requirement was evaluated using the N-Tester at the 6-leaf stage: the value was 420 which, according to the ANB calibration table, corresponds to a requirement of 40 units per hectare.

Results – Analysis of Graph 2 shows a statistically significant difference in gross saleable production value between the treatments applied with the hose and those with the sprinkler. In particular, the plots irrigated with the hose showed a 20-28% increase over the conventional fertilization associated with sprinkler irrigation. In terms of sugar content this increase was 9-17%. Moreover, for both irrigation methods, the best results were achieved with the application of microelements B and Mn in fertigation: 6-8% increase over the results obtained with water alone. As regards polarization, the application with hoses always proved significantly better: 14-17%. The worst DJP (dense juice purity) value was 89.80 obtained with sprinkler irrigation and conventional fertilization. This result was also statistically different from the other tests which showed a 1-2% increase. Finally, there was no statistically significant difference in beet yield between the tests, thus confirming the assumption that the different micro-irrigation systems, with and without fertigation, fundamentally affect polarization and other quality parameters.

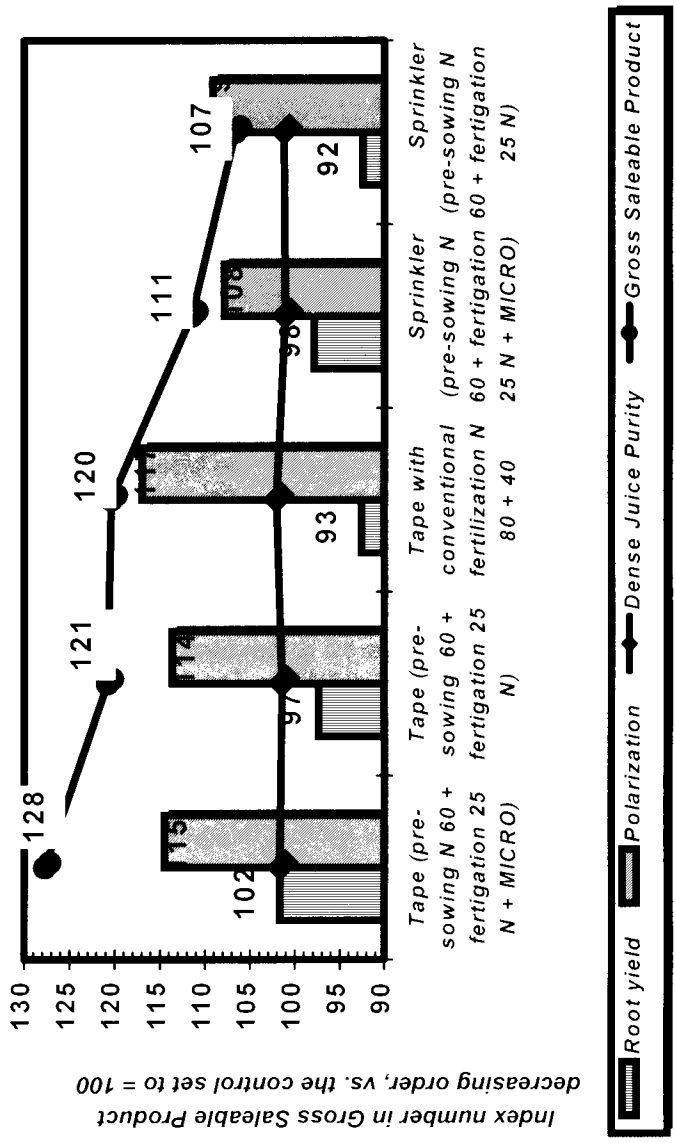
RADISH INTERCROPPING

Over the years the ANB Technical Service has performed more than 130,000 soil analyses for farmers in order to better evaluate the fertility of the soils used to grow sugar beets. These analyses have revealed a general lack of organic substances. In the last decade, the average values are now lower than 2% in nearly all regions, the sole exceptions being Friuli and Lazio where the values are around 2.5-3.5%, classifying the soil as having a high organic content.

The need to reintegrate soil fertility appears evident but the crisis in the zootechnical sector has made manure generally unavailable. ANB experimental tests have, however, shown that "green manures" with a high organic content can improve production and quality. Adding such intercropping to the rotation and plowing them under makes it possible to reintegrate lost organic substances.

Multi-year tests that ANB has performed in cooperation with the Institute of Agronomy of the Sacro Cuore University of Piacenza (Graph 3) using autumn cover crops (phacelia, barley, radish) prior to cultivation of sugar beets in the spring has highlighted that these catch crops can ensure:

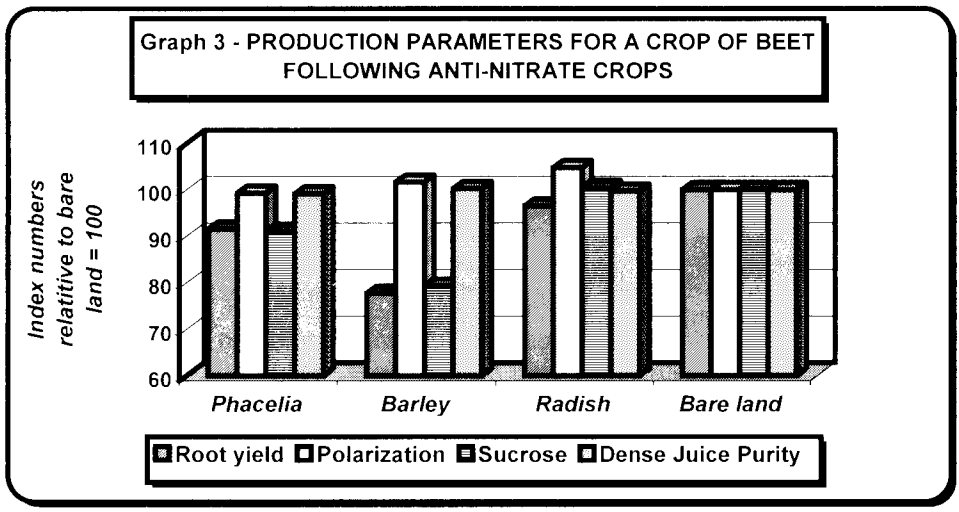
Graph 2 – Micro-irrigation and fertigation – Cesa (AR) – (in cooperation with CESA-ARSIA-Regione Toscana)



- nitrogen fixing during the autumn-winter period, thus reducing the risk of nitrates percolating into the water table;
- greater productivity when sugar beets are sown between rows of radishes at a distance of 45 cm. Moreover, these plants emerge sooner and show reduced failure. After radishes the terrain appears softer and does not require mechanical work before sowing the spring crop. The remaining cover can then be eliminated with a total herbicide followed by traditional inter-row operations (hoeing or better tilling).

Inserting radishes into the rotation is, in reality, also useful for their biocide action vs. the cyst nematode *Heterodera schachtii* which attacks sugar beets

and is rather widespread in the beet-growing areas of Northern Italy. The ANB study of autumn radish cultivation prior to sugar beets has, in fact, demonstrated a significant decrease (55%) in the live cysts and the eggs/larvae from early March. Evidently, extending the length of time the radishes remain in the field before sowing later crops such as maize, sorghum, sunflower, provides greater nematocide action leading to better soil health. Genetic evolution is a reality for the radish as well: the new varieties are more effective in pest control and are more resistant to low temperatures, a characteristic which is indispensable for crops sown in autumn.



CONCLUSIONS

A rational supply of fertilizers, in particular the extremely tricky nitrogen, must necessarily start from knowledge of the nutritional elements available in the soil. ANB has set up a nitrogen metering program based on the results of years of experimental testing. This program calls for soil analysis in the summer and autumn to identify the nature of the soil, its pH, c.s.c., C/N and Mg/K ratios as well as the lime content, organic substances, nitrogen, phosphorous, potassium, magnesium and micro-elements. This overall knowledge of the soil conditions, completed with winter check of nitrogen trends, makes it possible to meter nitrogen fertilization prior to sowing as well as other fertilization required throughout crop growth. This initial analysis must be followed by a crop cover control using an optical instrument, the N-tester which can determine the presence of chlorophyll within the leaves. The ANB tested correlation then permits this evaluation to measure how much nitrogen must be distributed in the spring while the crop is in the field.

ANB technicians are already making large-scale use of this nitrogen metering approach. The thousands of in-field checks conducted annually enable them to differentiate the advice they give for different areas, with doses that vary from 15-20 units per hectare in the eastern Po River Valley, to 40 units in the South and the western Po River Valley. Following this approach to application, there

has been an increase in sugar beet production, although it does vary from year to year depending on adverse weather conditions.

The experience acquired from this testing, performed in different areas, and the variability of the suggestions given even for adjacent areas, plainly indicate that a single all-inclusive "cure" able to meet all needs does not exist. Indeed it is clear that metered fertilization systems are needed. Only with such systems is it possible to administer the most suitable amounts of fertilizers, particularly of nitrogen, and this in turn leads to an evident improvement in productivity and product quality plus greater control over costs.

The experimental studies performed with micro-irrigation techniques in different Italian sugar beet realities indicate significant increases in sugar content when compared to dry cultivation: 40-50% in the North (Southern Po River Valley), 20-30% in the Northern Po River Valley, while it exceeds 100% in Central Italy.

With the advent of irrigation with low volumes of water (drip or micro-irrigators) it is also possible to apply dedicated fertigation which can provide limited amounts of fertilizers, in particular nitrogen, distributing them in combination with the irrigation water right when the crop needs them most. Years of ANB testing has found that this can reduce the amounts of minerals applied by 20-30%.

The fertility of the Italian sugar beet soils, impoverished by an increasing lack of organic substances, can be restored by autumn planting of certain crops at 45 centimeters between the rows so that the next spring sugar beets or other spring crops can be planted. Besides the organic substances provided by plowing this crop under, using crops such as radishes that have biocide activity, it is also possible to improve soil health, in particular clearing it of infestations of the cystic nematode *Heterodera schachtii*.

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