NITROGEN BUDGETING FOR TREE CROPS

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ABSTRACT

In recent years, nitrogen (N) budgets and the 4 R's approach (right rate, right time, right placement and right source) to N fertilizer management has been gaining more acceptance. In the N budget and 4 R's approach, fertilizers are applied in proportion to demand and timed with periods of N uptake. As a result, demand is satisfied in a timely fashion avoiding the application in excess of uptake capacity. While N is required for all plant processes, it is the specific growth and development patterns of different tree crops that determine how to execute the N budget. The total N in the harvestable crop removed from the field in addition to N allocated to vegetative and woody growth equals the N requirement. The rate of applied N fertilizer must also account for N credits from soil mineralization, organic matter amendments and cover crops, and N in irrigation water. Total N credits are deducted from the N requirement to derive the N demand to be met by supply of N fertilizer. Finally, fertilizer N demand is divided by an efficiency factor to equal the N fertilizer rate. Proper execution of timing, placement and source will result in meeting the targeted efficiency goal. The N budget and 4R's approach is a viable solution to efficient N use for tree crops in California and beyond however, barriers to implementation still remain.

PROBLEM

Nitrogen (N) is a limiting factor in productivity, a main source of non-point source pollution, and a challenge for stakeholders to adapt to management changes. Nitrogen is the most abundant plant essential nutrient and a limiting factor in crop productivity. Nitrogen is the basis for the enzyme rubisco found in chlorophyll and thus directly linked to photosynthetic capacity and carbon fixation. The development of industrial N fixation using the Haber Bosch process has greatly simplified N applications as a low-cost fertilizer and freed dependence on organic N sources, fallowing fields and mandatory crop rotation.

The simplicity of inorganic N fertilizer coupled with mechanization and irrigation has resulted in increased crop yields and economic gains. However, the elimination of N as a limiting factor in crop productivity has also lead to surplus fertilization. The application of N fertilizer beyond crop N demand lowers the risk of crop deficiency while uniform N application on heterogeneous soil types within the same field, simplifies management. This approach, however, frequently results in excess N in the crop system. The excess from surplus fertilization ultimately leads to N losses and pollution of the environment.

Fertilizer N losses are likely when soil N concentrations exceed crop capacity for N uptake. Soil N saturation from surplus fertilization creates conditions where N is a non-limiting factor for productivity and crop N demand. Soil N concentrations beyond N uptake capacity have the potential to be lost. The primary N loss pathways in agriculture are related to water management driven by wet and dry cycles. A greater potential for N loss is possible when residual nitrate remains after soil drying. During subsequent soil wetting from irrigation or precipitation, residual nitrate can be leached below the crop rooting zone or can undergo denitrification. Consequences of N losses include nitrate contamination of groundwater, impacts on surface water quality, and gaseous N losses as either dinitrogen gas or as the potent greenhouse gas, nitrous oxide [1].

Improvements in N management are required to maintain crop productivity while addressing pollution from N fertilizer use. The protection of air and water quality requires partnerships between multiple stakeholder groups [2]. In California, reporting N use to water coalitions as a part of the irrigated lands regulatory program offers baseline estimates of current management practices and an opportunity to monitor progress and identify inefficient practices. When practical, monitoring nitrate in groundwater can also serve to verify whether progress is being made toward pollution reduction goals. In many locations, however, the time and pathways for surface applied N to reach groundwater is too lengthy and uncertain for direct monitoring of groundwater to offer any information to assess practices or compliance. Ongoing education and outreach are critical to shift growers from inefficient practices toward N budgeting and the 4 R's approach and is an important component to facilitate adaptation.

NITROGEN BUDGET

In tree crops, the harvestable annual N removed from the field combined with N allocated to vegetative and woody growth equals the total N requirement. In order to calculate applied N fertilizer, N from other sources must be accounted for as N credits. Important non-fertilizer sources include mineralization of soil, organic matter amendments and cover crops, and nitrate in irrigation water. The total N requirement minus N credits equals fertilizer N demand. Fertilizer N demand is divided by an efficiency factor to calculate the N fertilizer rate. Efficiency factors for tree crops have been shown to range from less than 0.50 to greater than 0.80 [3]. Management practices like the 4 R's approach are required to realize a specific efficiency factor.

In the 4R's approach the right amount of fertilizer is applied at the right time to match tree demand and in the right place where the active roots are present so that the applied fertilizer is utilized by the crop. For many tree crops, remobilization of stored N is sufficient to meet the crop demand early in the season during flowering and fruit set until leaf out. This period is followed by soil N uptake from spring through summer when application of N fertilizer is appropriate. Different tree crops demand N at different growth stages depending on the primary N sink being fruit or vegetation. Nevertheless, effective N delivery is accomplished through timing split applications of N fertilizer along with crop demand.

The right placement of N fertilizer ensures delivery to the active root zone. Active roots represent a portion of the whole rooting system in tree crops. The depth of active roots is mainly found within the wetting front of irrigation water. Fertilizer N placement should also consider non-uniform distribution of yield potential and soil heterogeneity within fields. Uniform N application on large heterogeneous fields can lead to over fertilization in one area and under fertilization in another. Blocking non-uniform fields into smaller orchard units can improve efficiency. Finally, testing irrigation systems for distribution uniformity at least every 3 years is important to ensure N fertilizer is placed evenly throughout orchard blocks.

Leaf sampling is a useful adjunct to N budgeting and can be used to monitor response of crops to changing practices. The standard practice of summer leaf sampling is useful to identify the N status of the tree crop. However, summer leaf sampling can often be too late to correct a deficiency within season. To provide information on tree N status early in the cropping season an early season leaf sampling protocol has been developed [4]. The protocol includes collection of leaves from non-fruiting shoots 34-45 days after full bloom, followed by analysis for N, Ca, Mg, K, and B. With these data, a model predicts summer leaf N in spring. This approach offers a means to determine N status early enough to make adjustments within season and helps to avoid surplus fertilization if prediction of the summer leaf N in spring is sufficient.

TREE CROPS

The development of an N budget in tree crops depends on the type of crop such as nuts, deciduous fruits or subtropicals like citrus and avocado. Recent efforts focused on nut crops are vital due to their high N use and economic importance. In nut crops, annual fruit growth is the most significant component of N demand. Early N demand for flowers, fruit set and leaf out is met by remobilization of stored N from the perennial tissues. Following leaf out, tree N demand is met by uptake from the soil. Fruit N demand from different nut crops varies from 14 – 20 lb N per 1,000 lb in-shell yield for walnut, 28 lb N per 1,000 lb CPC yield for pistachio and 68 lb per 1,000 lb kernel yield for almond. The N demand accounts for the harvestable portion taken from the field including hulls, shells and kernel. Nitrogen allocation to vegetative growth decreases with greater yield and conversely, increases in young trees of nut crops.

Nitrogen demand from deciduous fruits is substantially lower than nuts. The majority of N in deciduous fruits is found in the seeds and stones. Fruit N demand for apple is 0.5 – 0.6 lb N per 1,000 lb fruit, 0.8 – 1.2 lb N per 1,000 lb fruit for peach, and 2.0 – 2.4 lb N per 1,000 lb fruit for cherry. Greater N demand for cherry is due to the stone making up a larger proportion of fruit mass. After harvest of deciduous fruits, a reduction in N demand occurs followed by remobilization of N from vegetative growth into woody storage [5]. Timing N application to match vegetative growth patterns is vital because vegetation is a greater sink for N demand in deciduous fruits and profound differences exist between early, mid-season or late-season varieties [6]. The high N demand for vegetation in deciduous fruits also creates an important N source from the mineralization of abscised leaves and tree prunings. Mineralization rates depend on soil conditions like soil temperature and moisture and orchard management like mowing or chopping. Mineralized N from leaves and prunings do not become exclusively available to tree roots for uptake but instead, is subject to competition with soil microbes [7].

Nitrogen budgets for subtropical crops like citrus and avocado require consideration of growth patterns and horticultural practices. Fruit N demand for citrus is similar to deciduous fruits at 1.3 lbs N per 1,000 lb fruit. Nitrogen uptake in citrus occurs from April to November and ceases during winter months [8]. Demand for N from vegetative growth depends on tree age with younger trees using more N for shoot and woody growth compared to older trees. Compared to citrus and deciduous fruits, avocado has greater N demand of 2.2-4.3 lb N per 1,000 lb of fruit. Growth of avocado fruit occurs over 12-18 months with an increase in fruit N demand from spring to fall and a leveling out in winter [9]. During the following spring when trees bloom and set a new crop, fruit from the previous year may still remain on the tree. This combination of new and mature fruit results in an additional period of high N demand.

IMPLEMENTATION

Implementation of N budgets and the 4R's approach in tree crops requires overcoming barriers of adoption through outreach and education. First, updating the knowledge base of N use in tree crops requires reconciling current scientific literature with ongoing research trials and county farm advisor recommendation for a diverse array of tree crops. Development of training content for certified crop advisors (CCAs) is underway since these professionals are a primary source of information for grower decision making with N fertilizer. Training including an overview of N in plant biology, N use in crop management and specific information on the similarities and differences of various tree crops offer sufficient content to train CCAs to make recommendations for the development of N budgets.

Multiple challenges exist to effectively integrate N budgets and the 4R's approach into the decision making of tree crop growers. Knowledge gaps exist like estimates of N turnover from leaves and prunings and N availability from cover crops and organic matter amendments. Simple technical solutions like solutions to manage irrigation systems across heterogeneous soils on the same field are also lacking. Additional barriers to adopt N budgets and the 4R's approach may include a poor understanding of return on investment, labor intensity, access to equipment and supplies, need for technical assistance or unknown effectiveness. Deciphering the benefits to motivate adoption is another complex question in need of further exploration. In conclusion, improvement of N use is necessary for tree crops in California, and despite the challenges, N budgets and the 4R's approach offer a viable approach.

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