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USE OF THE UNSTABLE ISOTOPE CARBON-11 FOR THE STUDY OF CARBON FIXATION TRANSPORT AND ALLOCATION IN ROOT AND TUBER CROP

Utilisation de l'Isotope instable Carbone-11 pour l'Etude de la Fixation du Transport et de Préparation du Carbone chez les Plantes à Tubercule

S.J. KAYS, J.D. GOESCHL
C.E. MAGNUSON, Y. FARES

University of Georgia, Athens, GA 30602 and Biosystems Research Group, Texas A & M University, College Station, TX 77843, U.S.A.

SUMMARY

The short-life isotope, ^{11}C, offers two extremely important advantages in the study of root and tuber crops. It emits a form of radiation (gamma rays) which can be measured quantitavely and nondestructively in intact plants and it decay quickly to background levels allowing the experiment to be conducted repeatedly on the same plant or group of plants.

We describe both the methodology utilized with 11 C and the actual fixation, transport and allocation of photosynthetic carbon in the sweet potato, *Ipomea batatas*. We monitored net carbon dioxide exchange; absolute photosynthesis; photosyntate pool sizes, turnover and storage rates, photosynthate export rate and direction, concentration and velocity of translocates throughout the plant; and source sink relationship through time. This information was used to develop strategies for genetically enhancing the productivity of the sweet potato and other root and tuber crops.

RESUME

L'isotope ^{11}C à courte vie offre deux avantages extrêmement importants pour l'étude des cultures de tubercule. Il émet des rayons gamma mesurables sans que l'on sacrifie la plante et revient rapidement à des niveaux normaux, l'expérience pouvant ainsi être répétées sur la même plante.

La méthodologie utilisée, la fixation, le transport et la distribution effective du carbone chez la patate Ipomea batatas *sont décrits. On a suivi l'échange net de CO2; la photosynthèse absolue; la dimension, les taux de rotation et de stockage des pools photosynthétiques; la direction et le taux d'exportation des produits photosyn-*

thétisés, la concentration et la rapidité des translocations à travers la plante; et les relations source-puits au cours du temps. Cette information a été utilisée pour élaborer des stratégies de renforcement génétique de la productivité de la patate et d'autres plantes à tubercule.

Plant breeding methods have evolved through a series of stages over the past 100 years to meet our needs for increased productivity. In the past, selection decisions were made largely upon final yield and the general resistance to insects and diseases. For many crop plants, however, we have reached a point where yield increases are becoming substantially more difficult to achieve. As a consequence, it has become increasingly essential for breeders to understand the many physiological and morphological interrelationships that collectively impart high yield in their respective crops. This, however, requires expertise well beyond the scope of genetics and plant breeding. Because of this, breeding is becoming more and more a team approach where physiologists, food scientists, entomologists, and pathologists work together with the breeders and molecular geneticists to develop new, higher yielding cultivars.

Plant growth is controlled by a number of complex, integrated biophysiological and biochemical processes. From kinetic studies of enzymatic control in biochemical pathways has evolved the concept of "rate limiting steps". A rate limiting steps represents the slowest single reaction in a series of reactions and a consequence is the major factor controlling the final rate at which the entire series of reactions can proceed. Thus, if we envision an extreme hypothetical case of a plant that has a single rate limiting step; e.g. the rate of chlorophyll synthesis in a low chlorophyll mutant, then genetically eliminating this step should result in a significant yield increase. In those cases where a single step significantly limits final yield, our success in genetically circumventing the problem is generally very good. More commonly, however, there are multiple steps that limit yield and our potential for success decreases exponentionally with the number of improved steps that must be incorporated into the new line. For example, in a series of reactions where the rate is indicated by the width of the arrow (Figure 1a), increasing the rate of reaction r_1 when the différential in rate between r_1 and r_2 is very small will result in an equally small increase in yield under ideal conditions. Likewise, when there are essentially equally rates for multiple steps ($r_1' \equiv r_5' \equiv r_7' \equiv r_{12}' \equiv r_{14}'$) (i.e. colimiting steps) in a series of integrated reactions (Figure 1b), the improvement in only one step will not result in an increase in yield. If one has exceptional luck and is able to incorporate simulanious improvements in each step, a large yield increase may be realized. However, if we improve 5 of the 6 steps and use final yield as our selection criteria, the progeny is going to be discarded.