Effects of Agronomy and Husbandry on Glucosinolates of Oilseed rape

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Commercial experience shows that considerable site and season variation occurs in the concentrations of glucosinolates in the seed of current oilseed rape cultivars, indicating that the genetic character for low seed glucosinolates is often over-ridden by soil, climate or husbandry factors. A joint programme of research, involving IACR-Rothamsted and Newcastle University was set up to provide a sound physiological and agronomic analysis of the variation in seed glucosinolates. Particular aims were to (a) determine the extents to which seed glucosinolates were influenced by practices used to grow and harvest the crop or were determined by soil and climatic factors at particular sites; (b) to examine glucosinolate accumulation in the vegetative and reproductive parts of the plant in relation to their presence in the seed; and (c) to establish whether a lowering of the concentrations of glucosinolates in the vegetative tissues would affect the susceptibility of cultivars to pests and diseases. The research was done between September 1987 and October 1990 on experiments at the two sites that tested the effects and interactions of a wide range of agronomic inputs predominantly on the double-low cv. Ariana, supplemented with some studies on new cultivars that subsequently appeared.

Effects of Agronomic Practices

Among the husbandry factors tested were time, rate and form of both nitrogen and sulphur fertilisers; time of sowing, seed rate, row spacing and plant population; applications of insecticides and fungicides to control pests and diseases and of plant growth regulators to modify crop structure. Another 3-year series of experiments examined the effects of time and method of harvest.

Most agronomic practices had no effect on seed glucosinolates. Consistent, small improvements in seed glucosinolate concentration were obtained by sowing in September as compared with August or October, and as a result of controlling pathogens with fungicides. However, both responses were generally small (2-4 μmol g^{-1}). Two factors that consistently increased seed glucosinolates were nitrogen and sulphur and usually the amounts applied affected concentrations more than the timing of applications. In the case of sulphur, concentrations were increased more by soil applications of inorganic sulphur than by foliarly-applied elemental sulphur.

Trials at Newcastle and Rothamsted have shown that glucosinolate concentrations are consistently increased by increments of nitrogen over the range 0 to 150 kg ha^{-1} with the increase ranging from 5 μmol g^{-1} at Rothamsted to 10 μmol g^{-1} at Newcastle. Plant-density trials at Rothamsted showed that seed glucosinolate concentrations continued to increase with nitrogen rates well above 150 kg ha^{-1} but only at low densities, suggesting that concentrations are influenced more by the amounts of N taken up by individual plants than the total amount applied to the crop.

Oilseed rape crops showed little response in yield or seed glucosinolate concentration to applied sulphur at Newcastle and sites in south-east Scotland where sulphur was not deficient and leaf sulphur concentrations were greater than 0.5% at the start of flowering. On other light-textured soils in south-east Scotland, crops had leaf sulphur concentrations between 0.36 and 0.41% and applications of sulphur to these increased seed glucosinolate concentrations by over 8 μmol g^{-1} per 100 kg of applied S ha^{-1}.

Significant interactions have been observed between the effects of sulphur and nitrogen fertiliser on seed glucosinolate concentrations. These interactions of nitrogen and sulphur may partly contribute to site and season differences in seed glucosinolates. At Newcastle, large applications of nitrogen (> 200 kg ha^{-1}) increased seed glucosinolate concentrations when large amounts of sulphur (> 50 kg ha^{-1}) were also applied. At low sulphur deposition sites in south-east Scotland, similar large applications of nitrogen also increased concentrations when large amounts of sulphur were applied, but *decreased* seed glucosinolate concentrations from 12.6 to 7.2 μmol g^{-1} when no sulphur was given.

It would appear that the crop's nitrogen:sulphur balance regulates the synthesis and/or accumulation of glucosinolates in seed. When sufficient sulphur is available, an increased supply of nitrogen enhances the synthesis of amino acids especially those containing sulphur that are the precursors for glucosinolate biosynthesis. When the amount of sulphur is limited, most of it is used in primary metabolism, leaving less available for secondary metabolites such as glucosinolates.

When crops were swathed or desiccated at the correct time, there were no deleterious effects on seed glucosinolate concentrations. If applied when pods and seed were immature, both swathing and desiccation greatly increased concentrations showing that such treatments should be used with care on unevenly-ripened crops.

The main conclusion from the study was that considerable variation in seed glucosinolate concentrations occurs between seasons, between sites, between fields at a particular site, between plants within a field and between branches on the same plant. Only a small part of this variation can be attributed to the husbandry used to grow the crop. Particular soil factors and seasonal differences in weather are more likely to be responsible. Applications of nitrogen and sulphur, and perhaps natural variations in the supply of these nutrients from the atmosphere and soil, alter glucosinolate concentrations, but it is not clear how. So far, the interactions of these factors have not been studied over a sufficiently wide range of conditions for the underlying physiological mechanisms to be fully understood and variations in seed glucosinolates to be confidently predicted. Such studies are the basis of new research.

The Physiology of Glucosinolate Accumulation in Seeds

Measurements of changes in seed glucosinolates during seed development showed that concentrations increased only during active seed growth and not during seed maturation. Large seasonal differences occurred in the patterns of glucosinolate concentration both between sites and between seasons at a single site. In some years these differences could be attributed to greater glucosinolate accumulation and in others to greater seed growth diluting the glucosinolates. Therefore, the two processes of seed growth and the accumulation of glucosinolates within them can vary independently of each other and are likely to be affected by different factors. For instance, crop sulphur and nitrogen status probably influence glucosinolate synthesis and accumulation, whereas seasonal weather (e.g. temperature, radiation and water availability) and perhaps some husbandry factors (e.g. use of fungicides) probably have greater effects of seed numbers and size.

Glucosinolates in Vegetative Tissues

Glucosinolates occur in all parts of the plant and these studies showed that large changes occurred in both types and amounts between cultivars and in the various tissues as growth progressed. It is thought that breakdown products of glucosinolates protect the plant when they are attacked by certain pests and diseases. There is concern that continued breeding for low seed glucosinolates might also decrease their occurrence in the rest of the plant and increase the need for crop protection. Our measurements showed that the selection for the low seed glucosinolate character has resulted in smaller overall amounts of glucosinolates being produced in the vegetative parts of the plant, especially in some of the more recently-introduced cultivars, and lower concentrations of specific glucosinolates in particular tissues. There is no conclusive evidence that such changes have affected the susceptibility of such cultivars to pests and diseases, but some do show greater yield response to high pesticide inputs.