SHORT COMMUNICATION

Near-infrared versus visual sorting of *Fusarium*-damaged kernels in winter wheat

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Wegulo, S. N. and Dowell, F. E. 2008. **Near-infrared versus visual sorting of *Fusarium*-damaged kernels in winter wheat**. Can. J. Plant Sci. **88**: 1087–1089. Fusarium head blight (scab) of wheat, caused by *Fusarium graminearum*, often results in shriveled and/or discolored kernels, which are referred to as *Fusarium*-damaged kernels (FDK). FDK is a major grain grading factor and therefore is routinely determined for purposes of quality assurance. Measurement of FDK is usually done visually. Visual sorting can be laborious and is subject to inconsistencies resulting from variability in intra-rater repeatability and/or inter-rater reliability. The ability of a single-kernel near-infrared (SKNIR) system to detect FDK was evaluated by comparing FDK sorted by the system to FDK sorted visually. Visual sorting was strongly correlated with sorting by the SKNIR system ($0.89 \leq r \leq 0.91$); however, the SKNIR system had a wider range of FDK detection and was more consistent. Compared with the SKNIR system, visual raters overestimated FDK in samples with a low percentage of *Fusarium*-damaged grain and underestimated FDK in samples with a high percentage of *Fusarium*-damaged grain.

Key words: Wheat, Fusarium head blight, *Fusarium*-damaged kernels, single-kernel near-infrared

Wegulo, S. N. et Dowell, F. E. 2008. **Tri visuel ou dans le proche infrarouge des grains de blé d'hiver abîmés par *Fusarium***. Can. J. Plant Sci. **88**: 1087–1089. La brûlure de l'épi du blé (gale) causée par *Fusarium graminearum* produit souvent des grains momifiés ou décolorés. Ce problème affecte considérablement le classement, de sorte qu'on le surveille de manière routinière pour garantir la qualité du produit. On jauge couramment la quantité de grains momifiés visuellement. La tâche est parfois laborieuse et manque d'uniformité car on note des variations tant au niveau de la reproductibilité par le même préposé au classement que de la fiabilité d'un préposé à l'autre. Les auteurs ont évalué la capacité d'un système d'analyse dans le proche infrarouge à détecter les grains momifiés en comparant le nombre de grains repérés par l'appareil à celui déterminé par examen visuel. Il existe une étroite corrélation entre le tri visuel et le tri dans le proche infrarouge ($0{,}89 \leq r \leq 0{,}91$); toutefois, l'appareil détecte plus de grains momifiés et les résultats sont plus uniformes. Comparativement au système infrarouge, les examinateurs surestiment la quantité de grains momifiés dans les échantillons peu contaminés par *Fusarium* et la sous-estiment dans ceux renfermant beaucoup de grains endommagés.

Mots clés: Blé, brûlure de l'épi causée par *Fusarium*, grains momifiés , examen dans le proche infrarouge

Fusarium head blight (FHB) or scab, caused by *Fusarium graminearum* Schwabe, is a destructive disease of wheat. FHB causes premature bleaching of spikelets on the wheat head (Wiese 1987). Bleached spikelets are either sterile or contain shriveled and/or discolored kernels, commonly referred to as *Fusarium*-damaged kernels (FDK) (Dexter and Nowicki 2003; Schaafsma et al. 2004). The higher the percentage of FDK in the harvested grain, the lower the yield, test weight and quality of the grain (Tuite et al. 1990; McMullen et al. 1997; Dexter and Nowicki 2003). In addition, *F. graminearum* produces the mycotoxins deoxynivalenol (DON) and, to a lesser extent, zearalenone. These mycotoxins contaminate grain, posing potential food and feed safety hazards (McMullen et al. 1997; Dexter and Nowicki 2003). The marketability of *Fusarium* damaged wheat is limited by the adverse effects of the disease on milling performance, flour properties, and end product quality (Dexter and Nowicki 2003). Because FDK is a major grain grading factor (USDA 2006), it is routinely measured for purposes of quality assurance. FDK determination is a routine grain inspection procedure carried out by the Grain Inspection, Packers and Stockyards Administration (GIPSA) (USDA 2006). Measurement of FDK usually is done visually. Visual sorting of grain for FDK can be laborious especially if many samples need to be sorted. Furthermore, if several raters sort grain for FDK, as often is necessary, inconsistency can result from variability in intra-rater repeatability and/or inter-rater reliability (Nutter et al. 1993; Nita et al. 2003).

Abbreviations: FHB, Fusarium head blight; **FDK,** Fusarium-damaged kernels; **SKNIR,** single-kernel near-infrared

Alternative methods to visual sorting include image analysis and near-infrared spectroscopy (Schaafsma et al. 2004). Dowell et al. (1999) used near-infrared spectroscopy to detect *Fusarium* damage in single wheat kernels by manually placing the kernels in the spectrometer viewing area. This method is nondestructive, simple, and can be put to uses other than FDK determination (Schaafsma et al. 2004). In addition, using near-infrared spectroscopy can eliminate the inconsistency associated with visual sorting. The single-kernel near-infrared (SKNIR, Perten Instruments, Stockholm, Sweden) system used in this study is automated, which saves the time needed to manually place individual kernels in the spectrometer viewing area as was done with the previous system (Dowell et al. 1999). The system used in this study was developed and used to non-destructively sort wheat kernels based on protein content and hardness and proso millet (*Panicum miliaceum* L.) into amylose-bearing and amylose-free fractions (Dowell et al. 2006). This system feeds single kernels into a near-infrared spectrometer, and then sorts each kernel into either a healthy or FDK portion using a partial least squares regression calibration model. The SKNIR system and typical model development procedures were described by Dowell et al. (2006). Samples for the scab calibration were prepared by visually sorting about 1300 kernels (130 kernels from each of 10 samples obtained from Dr. Gene Milus, University of Arkansas) into asymptomatic and FDK portions. These samples were then scanned and the two portions were assigned a value of "1" for healthy kernels or "2" for FDK based on the calibration developed from a partial least squares regression. The objective of this study was to assess the ability of the SKNIR system to detect FDK in wheat grain by comparing visual sorting to sorting by the SKNIR system.

To assess the ability of the SKNIR system to detect FDK, four 100-kernel subsamples from each of 21 samples were sorted by the system. The samples were obtained from fields, a grain inspection facility, and elevators in south central and eastern Nebraska, USA, an area where severe epidemics of FHB occurred in 2007. The 84 subsamples sorted by the SKNIR system were visually sorted for FDK by an experienced rater and a recently trained rater. FDK was visually determined by counting the affected kernels in each subsample. Kernels were considered *Fusarium*-damaged if they had a chalky-white or pinkish appearance and/or were shriveled.

Data were analyzed using the GLM procedure of SAS version 9.1 (SAS Institute, Cary, NC). FDK means (the average of four subsamples from each of the 21 original samples) were used in analysis. Consistency in sorting FDK by the SKNIR system and the two raters was evaluated by examining standard deviations of the mean FDK values. Linear correlation coefficients (Steele et al. 1997) were used as a measure of (i) the agreement in FDK sorting between raters and between each rater and the SKNIR system (inter-rater reliability), and (ii) the agreement in FDK sorting between runs by each rater and by the SKNIR system (intra-rater repeatability).

Agreement in FDK sorting between the SKNIR system and the two raters (inter-rater reliability) was strong. Correlation coefficients between the SKNIR system and the raters were $r = 0.91$ (rater #1) and $r = 0.89$ (rater #2). These results are consistent with those from a study by Dowell et al. (1999) in which it was demonstrated that a near infrared system could correctly identify all kernels with visible *Fusarium* damage as determined by official inspection. Agreement between the two raters (inter-rater reliability) also was strong ($r = 0.91$). Agreement between replicate runs in sorting FDK (intra-rater repeatability) was strongest for the SKNIR system ($0.91 \leq r \leq 0.96$, $P < 0.0001$) followed by rater #1 ($0.68 \leq r \leq 0.80$, $P \leq 0.0007$) and rater #2 ($0.49 \leq r \leq 0.66$, $P \leq 0.0236$).

The mean FDK in each of the 21 samples ranged from 1 to 71% for the SKNIR system, 7 to 51% for rater #1 and 4 to 44% for rater #2 (Fig. 1). These results imply that the SKNIR system had a wider range of FDK detection than the raters. Compared with the SKNIR system, the raters generally overestimated FDK in samples with a low percentage of *Fusarium*-damaged grain and underestimated FDK in samples with a high percentage of *Fusarium*-damaged grain (Fig. 1). Plots of standard deviations of FDK means showed that the SKNIR system was more consistent in sorting FDK than the two raters (Fig. 2).

In this study, a SKNIR system was better than human raters in sorting FDK, since it had a wider range of FDK detection and was more consistent. There are several advantages to sorting FDK by the SKNIR system. The expertise required to use the system is much less than that needed to train someone to visually

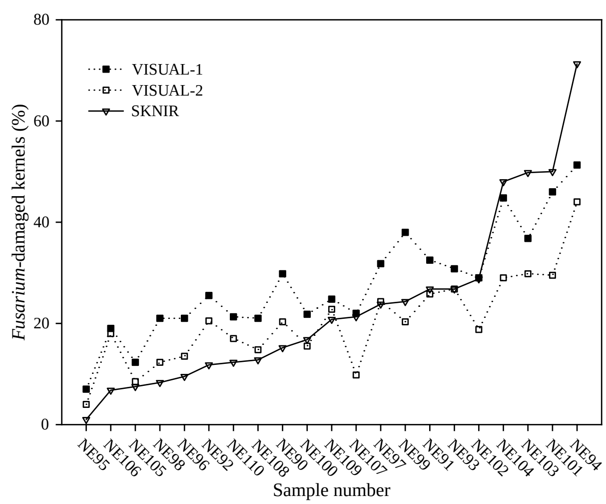

Fig. 1. *Fusarium*-damaged kernels detected by a single-kernel near-infrared system (SKNIR) and by two raters (VISUAL-1 and VISUAL-2).

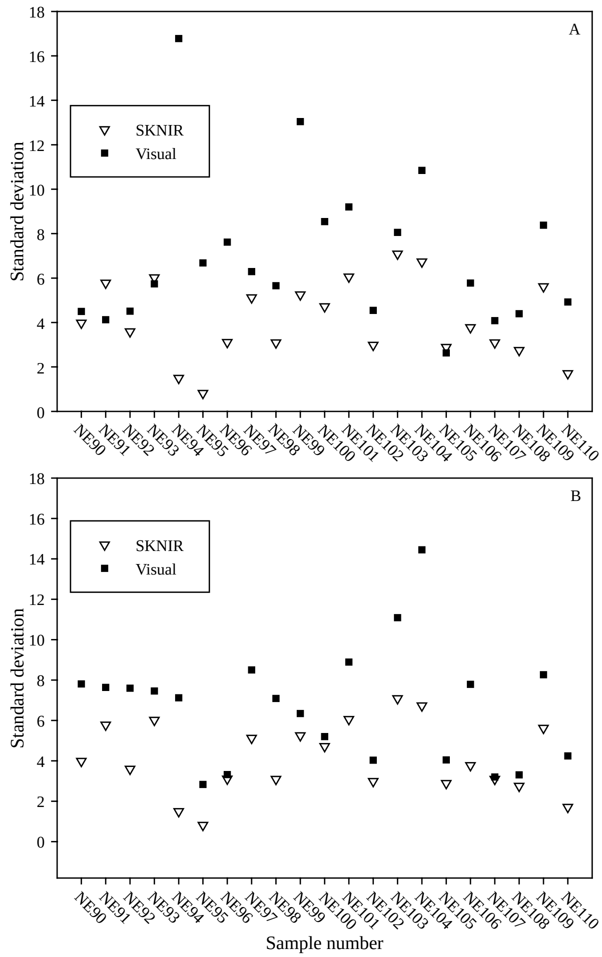

Fig. 2. Standard deviations of the mean of the percentage of *Fusarium*-damaged kernels sorted by a single-kernel near-infrared (SKNIR) system and visually by raters 1 (A) and 2 (B).

sort FDK. Standard deviations of FDK means were consistently lower when sorting was done with the SKNIR system compared with visual sorting. Furthermore, it was demonstrated that although inter-rater reliability and intra-rater repeatability were good, there still was fluctuation in visual sorting by the same rater and between raters.

The system can sort a 100-kernel sample in less than 5 min. An additional 1 to 2 min is needed for the operator to remove the sorted sample and to load the next sample into the instrument. The instrument does not require user intervention during sorting. Thus, the operator can work on other tasks during the time required to sort the sample. The two raters who visually sorted FDK in this study took 10 h (rater #1) and 8 h (rater #2) to sort 84 samples, i.e., 8.4 and 10.5 samples per hour, respectively. The SKNIR system sorts at a rate of approximately 8.8 samples per hour. Therefore, the SKNIR system and the raters sorted FDK at comparable rates. However, for every sample, the SKNIR system operator would have 5 min (i.e., 44 min/hour) to do something else, whereas a visual rater would be sorting continuously.

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