Image analysis for the detection of three-horned bedstraw seed in grain

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Summary Knowing the extent of a weed infestation is required to justify a weed eradication program as this has a large influence on the benefit:cost ratio. Detecting weeds at low levels is difficult and expensive as large numbers of samples are required. For weeds that contaminate grain, many samples can be collected cheaply as the grain is delivered for sale and these can be screened for weed seed. Using image analysis allows large numbers of samples to be screened quickly. This paper describes a system where a video camera is set up over a conveyor belt and the images are analysed for the presence of three-horned bedstraw (*Galium tricornutum*) seed. The image analysis software is trained by passing contaminated grain through the system where 25 characteristics of suspect objects are recorded. Discriminant analysis is then used to develop a formula that distinguishes the three-horned bedstraw from similar looking objects. Grain to be screened is then passed through the machine. When a suspect seed is detected the grain is automatically diverted to a separate container. Grain from this container is then manually scanned or put through the machine again to further concentrate the sample.

Keywords Australia, declared weed, discriminant analysis, *Galium tricornutum*, grain samples, Halcon, image analysis, seed detection, three-horned bedstraw.

INTRODUCTION

Three-horned bedstraw (*Galium tricornutum* Dandy) is a declared weed that is currently the focus of an eradication campaign in Western Australia (Moore and Dodd 2008). Knowing the extent of a weed infestation is required to justify a weed eradication program as this has a large influence on the benefit:cost ratio. Detecting weeds at low levels in the environment is both difficult and expensive and large numbers of samples are required. For weeds that contaminate grain, many samples can be collected cheaply as the grain is delivered for sale and these can be screened for weed seed.

Using image analysis allows large numbers of samples to be screened quickly. This paper describes a system where a video camera is mounted over a conveyor belt and the images are analysed for the presence of three-horned bedstraw seed.

MATERIALS AND METHODS

A machine was built based on an old conveyor belt pot sprayer. An accurate feeding mechanism delivers grain to the belt, which then travels under the video detection system and then on to a drafting gate mechanism where grain containing suspect seeds is directed into a separate container for further analysis (Figure 1). The belt must travel at a constant speed because the drafting gates are operated at a precise time after a seed is detected. The maximum speed of the belt is limited by the speed of the detection algorithm and the horizontal distance between the camera and drafting gates. (Our machine is 1 m s^{-1}.) We used a pair of rollers as the grain feeding mechanism because this gave an even distribution of seed on the belt. The rollers are connected to a very low speed 12 volt motor, which is connected to a speed controller so the feed rate may be adjusted to give reasonable separation between individual grains on the belt. The video camera is attached to a computer running the Halcon 9 image analysis software and software developed by us.

Detection is a two stage process. The Halcon software captures the image from the camera and identifies objects within a user specified size range and returns 25 characteristics for each seed or object. These are passed to the second stage which applies an algorithm to determine if the object is similar to bedstraw. If so, the program sends a pulse to open the appropriate drafting gate to separate the seed from the bulk sample. The characteristics and an image are also stored in a database so that an alternate algorithm could be used in the future to search for other contaminants.

To train the system, bedstraw seeds and a sample of bedstraw free grain including wheat, barley, oats, canola, lupins and peas were passed under the camera in two separate runs and the 25 characteristics recorded. Discriminant analysis is used to produce a formula that best separates the bedstraw from the grain and other debris. This formula is entered into the program for analysing future samples potentially containing bedstraw.

Grain samples to be screened are passed through the machine. When a suspect seed is detected the grain is automatically diverted to a separate container. Grain from this container is then manually scanned or

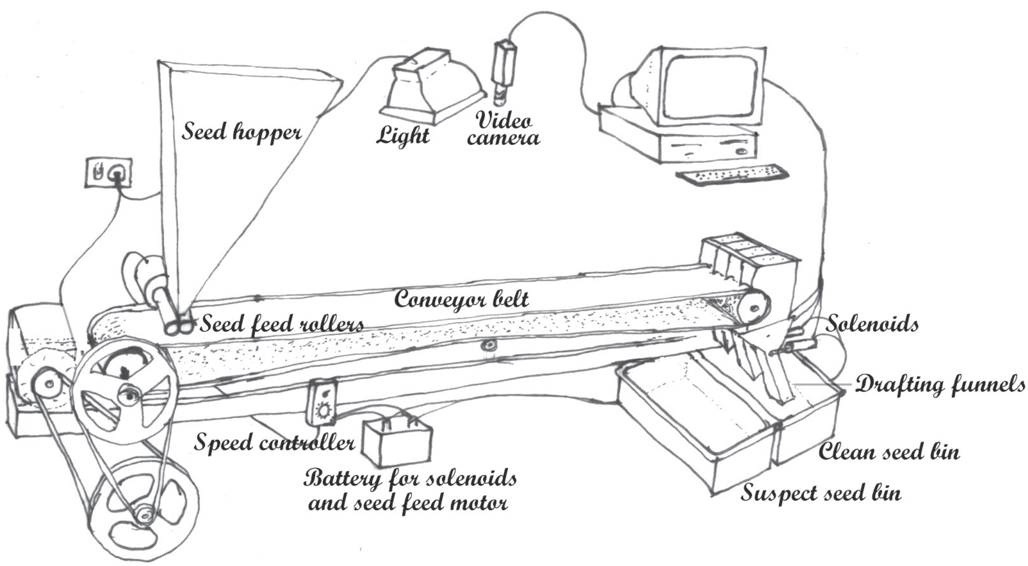

Figure 1. The setup of the machine for detecting foreign seeds in grain samples.

put through the machine again to further concentrate the sample.

Samples that had been visually inspected and known to contain bedstraw were used to test the system initially. Five hundred and twenty-three samples were collected from trucks delivering grain and were screened to determine the prevalence of bedstraw. This was analysed to estimate the probability of undetected infestations in the region based on prior experience that crops from infested areas had more than one bedstraw seed per kilogram of grain

RESULTS

An accuracy of 98% detection was regularly achieved for bedstraw in the cereal grains. In canola the accuracy was typically around 90% because the bedstraw seed is very similar in size and colour to canola. As more and varied samples are tested, the characteristics associated with false positive readings will be collected and a better discriminant function can be produced. For example some of our samples had grain staining or small rocks that were being classified as bedstraw seed based on the first function we used. In canola samples, the discriminant function could not absolutely distinguish between bedstraw seeds and other objects as shown by the overlap between the classes in Figure 2.

A significant amount of programming was required to take the data captured by the Halcon software, store it and analyse it quickly enough to operate the drafting gates before the seed had arrived at the gates.

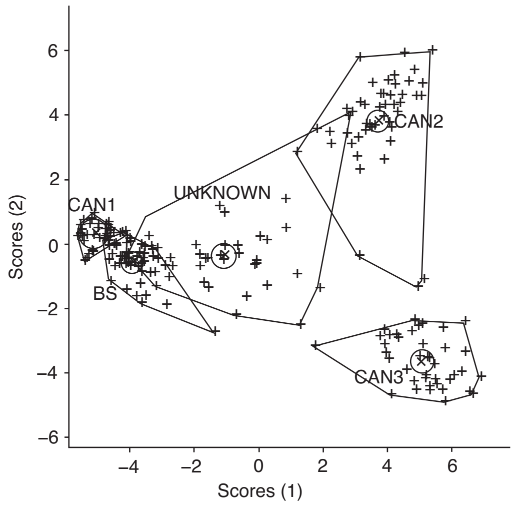

Figure 2. Discriminant analysis plot of bedstraw (BS), three classes of canola (CAN1, CAN2, CAN3) and other objects (UNKNOWN) from canola grain samples.

The throughput is about 100 kg per hour. For 1 kg samples the system typically produces about 1 g of sub-sample that requires visual inspection to find bedstraw seed. In our application the sub-sample is mainly false positives as the algorithm is set to ensure a low level of false negatives and thus a low chance of not detecting bedstraw if it is present. About 100 samples of 1 kg are typically processed in 1 day due to the time taken to load, dispose and record individual samples.

No bedstraw was detected in the 523 samples collected from grain delivery locations. From this sampling intensity it can be stated with 90% confidence that there are no infestations greater than 1025 ha. Alternatively we can also say with 90% confidence that infestations of less than 25 ha would not be detected with this number of samples. This is based on a conservative estimate that even lightly infested crops have more that one seed per kilogram of harvested grain, the average yield is 2000 kg ha^{-1} and there is 245,400 ha cropped in the target area.

DISCUSSION

The system is suitable for detecting bedstraw in large numbers of small samples and for reducing the size of large samples by about 99.9%. The sample needs to be fed through slowly enough to allow reasonable separation between individual seeds on the belt. Currently it is not suitable for deployment on commercial conveyor belt systems where there is a depth of grain on the belt.

The main benefit has been the ability to process a large amount of grain and reduce it to a small quantity that requires inspection. The ability to more accurately discriminate bedstraw seed from other objects could be improved by placing the camera closer to the sample but this reduces the throughput. Granitto *et al.* (2002) has also used machine vision for identifying individual weed seeds and their system could be used to distinguish bedstraw in the concentrated samples produced by our system. As their system uses one frame per seed it is of limited use for screening very large quantities of seed that need to be processed to detect low levels of contamination.

It is estimated that the cost per sample is 90% less than normal visual screening. The relative accuracy of the two methods under normal conditions has not been compared.

As the number of samples processed increases each year, the confidence in detecting smaller infestations will increase or new infestations will be detected. This information is required to make rational decisions about the funds that should be invested in eradication programs (F.D. Panetta pers. comm.).

The system is also being tested to detect insects and other contaminants in grain. Low cost surveillance for contaminants in grain is likely to become more important as more quality assurance conditions are imposed.

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REFERENCES

Granitto, P.M., Navone, H.D., Verdes, P.F. and Ceccatto, H.A. (2002). Weed seeds identification by machine vision. *Computers and Electronics in Agriculture* 33, 91-103.

Moore, J.H. and Dodd, J. (2008). Eradication of three-horned bedstraw (*Galium tricornutum*) in Western Australia. Proceedings of the 16th Australian Weeds Conference, eds R.D. van Klinken, V.A. Osten, F.D. Panetta and J.C. Scanlan, pp. 60-2. (Queensland Weeds Society, Brisbane).