Pod loss assessment methods to quantify yield loss in chickpeas; scoring is quick and correlates with counts

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Abstract

Wet weather can delay the harvest of chickpea and contribute to yield loss through post senescence pod drop. Accurate methods are required to determine the contribution of pod drop to yield loss and identify genotypes with limited pod loss. We developed a pod loss scoring system and compared this method to field pod counts and digital image pod counts. To determine how pod counts related to yield loss we retrieved pods and seeds from the soil surface. The methods were evaluated across three root disease experiments in NSW in 2020 where harvest had been delayed for a six week period. The value of the pod scoring method was that it correlated to both field counts (r^2=0.72-0.96 and image based (r^2=0.79) pod count methods and could be carried out quickly. Counts from images and field counts provided more accurate estimates than scoring, but both of these methods were more time consuming and may not be achievable when time or resources are limited. The pod loss score method underestimated the actual seed numbers retrieved from the top 20mm of trash and soil, due to some pods and seed being covered. Therefore, if pod loss assessments needs to be converted to grain loss estimates, surface samples to determine background levels will need to be collected. Regression relationships from the three pod loss methods (r^2=0.73-0.83) were used to predict grain weight loss. Results showed that all chickpea genotypes had lost proportionally more than 20% of their grain weight, there was a significant range in losses with one genotype losing proportionally more than 50% of its grain weight. The extent of pod loss was not related to the yield of genotypes. In summary, the scoring method provided useful results, but the digital image method allows rapid field assessments which if they could be supported by automated image counting methods would provide more accurate results than scoring.

Keywords

Chickpea, harvest delay, pod counts, pod loss, yield loss.

Introduction

The loss of grain yield due to pod shattering or complete pod abscission is a major concern in pulse production (Ogutcen et al. 2018). Pod number is a major yield component in chickpea (Upadhyaya et al. 2002). Wet weather at crop physiological maturity can also delay the harvest of chickpea, the relative contribution to yield loss through pod drop prior to a delayed harvest remains undescribed. Previous research has focussed on the amount of desi chickpea grain lost during the harvest process under conditions that did not promote grain or pod loss prior to harvest (Daniel et al. 2019).

There are many pod or seed counting methods including manual counting, the use of electric seed counters, and digital image analysis. There are several automated digital image analysis programs, however, these cannot be used with field based images and seeds cannot overlap or touch one another (Mussadiq et al. 2015). We are not aware of any method developed for the counting of abscised pods. Therefore, accurate methods are required to determine the contribution of pod drop to yield loss and to identify genotypes with limited pod loss, especially in the context of weather delayed harvests. We sought to evaluate field based methods to quantify pre-harvest pod and seed loss in the context of delayed harvest of chickpea. Such methods may be useful in other pulse crops.

Methods

Pod losses were determined in three phytophthora root rot by chickpea genotype experiments in NSW in 2020 which had grain harvest delayed due to significant rainfall. All experiments were split plot for *Phytophthora medicaginis* inoculation, with 1500 oospores applied per seed in furrow at sowing and four replicates. Experiment 1 had 16 genotypes (14m^2 plots, 128 plots), Experiment 2 had 10 genotypes (14m^2 plots, 80 plots), Experiment 3 had 2 genotypes (4.2m^2 plots, 64 plots). All experiments were sown from 1 to 2 July 2020, plants reached physiological maturity at the end of November, on 4 December all plots were foliar desiccated (135g/L paraquat, 115g/L diquat, 700g/kg saflufenacil, 120 l/ha) but frequent rainfall through December and early January prevented header access and grain harvest.

For each experiment, in the second week of January, plants were manually harvested in a $1m^2$ quadrat/plot. Plants were harvested with methods to capture any pods or seed that became detached during the harvest process. This was achieved by cutting stems at a height of approximately 50 mm with an electric cutter, polypropylene sacks were then slid over the cut stem bases to cover the soil surface, then the severed plant and pods were placed into sacks, any pods or seeds detached in the harvest process were collected on the surface placed sacks and added to the harvest sample, these samples were dried, threshed and grain yield determined. Following plant removal, a number of assessments were made with the time each method took to complete recorded:

1. The $1m^2$ ground area was scored for pod loss in three experiments. For the largest experiment, all plots were visited to identify the plots with the minimum and maximum number of pod loss, these plots were photographed and used to establish endpoints and the midpoint of a 10 point scale. All plots were then scored, using the photographs as a guide where a score of 1 represented low, 5 represented moderate and 10 represented high pod loss plots. This method provided pod loss score (PS) assessments.

After scoring, the pod scores values were assessed and a minimum 12 plots per experiment were selected which covered the range in pod loss in each experiment. These selected method validation plots were spread evenly across replicates and received the following additional assessments.

2. For Experiment 1 a digital photograph of each quadrat area was taken with Olympus Tough TG-5 digital camera between 11 and 2 pm, all images were taken from a fixed position, on the southern side of each plot. The camera resolution was set to 314 dpi and an image size of 2.9 MB was obtained. After the experiment was completed, the number of pods in each digital image was counted by using four grid sections placed over the digital images. This method provided pod loss image count (IC) assessments.
3. At the method validation plots, the number of pods on the soil surface per quadrat was counted and recorded. This method provided pod loss count (PC) assessments.
4. After the field count assessment, the pods were collected in each quadrat by brushing the loose surface soil and plant trash to an approximate depth of 20mm, this material was removed and oven dried at 40°C for 48 hours. Pods were then threshed with an Almaco Belt thresher, BT14® (Iowa, USA). Further sieving (3.35 mm aperture sieve) was required to separate all soil, then the number of seeds was counted. This method provided seed sample (SS) count assessments, and samples weighed to provide grain weight loss assessments.

Linear regression was used to examine relationships between pod loss assessments methods with the validation sets. ANOVA was used where there was assessment data for all plots in an experiment. For Experiment 1 from the PS and PC methods versus SS count regression equation for each experiment, the number of seeds lost for each genotype was predicted and plotted against the genotype pod loss scores, using the hundred seed weight of each genotype the weight of seed lost per quadrat was calculated, then the proportion of lost seed to total seed harvested and lost seed calculated.

Results

The time taken to complete the methods varied; Experiment 1, PS 1 min./plot, PC 13 min./plot and IC method, photograph 1.3 min./plot, pod counts 9.8 min./image, total time 11.1 min./plot; Experiment 2, PS 1 min./plot, and PC 15 min./plot.; Experiment 3, PS 1 min./plot and PC 15min./plot.

The strength of the relationship between three pod loss assessment methods differed in Experiment 1, however, relationships between all methods ranged from being moderately (r^2=0.71) to strongly correlated (r^2=0.93) (Figure 1). For the other two experiments relationships between the pod count and pod score methods were also strong for Experiments 2 (r^2=0.93) and 3 (r^2=0.96).

Regression results for the pod loss methods against the number of seeds retrieved from the top 20 mm of surface trash and soil, indicated that a pod loss score of 1 would predict a loss of 172 seeds (Figure 1d). Y intercept values for the field and the image pod count methods gave respective values of 12.8 and -20 seeds (Figure 1 e, f).

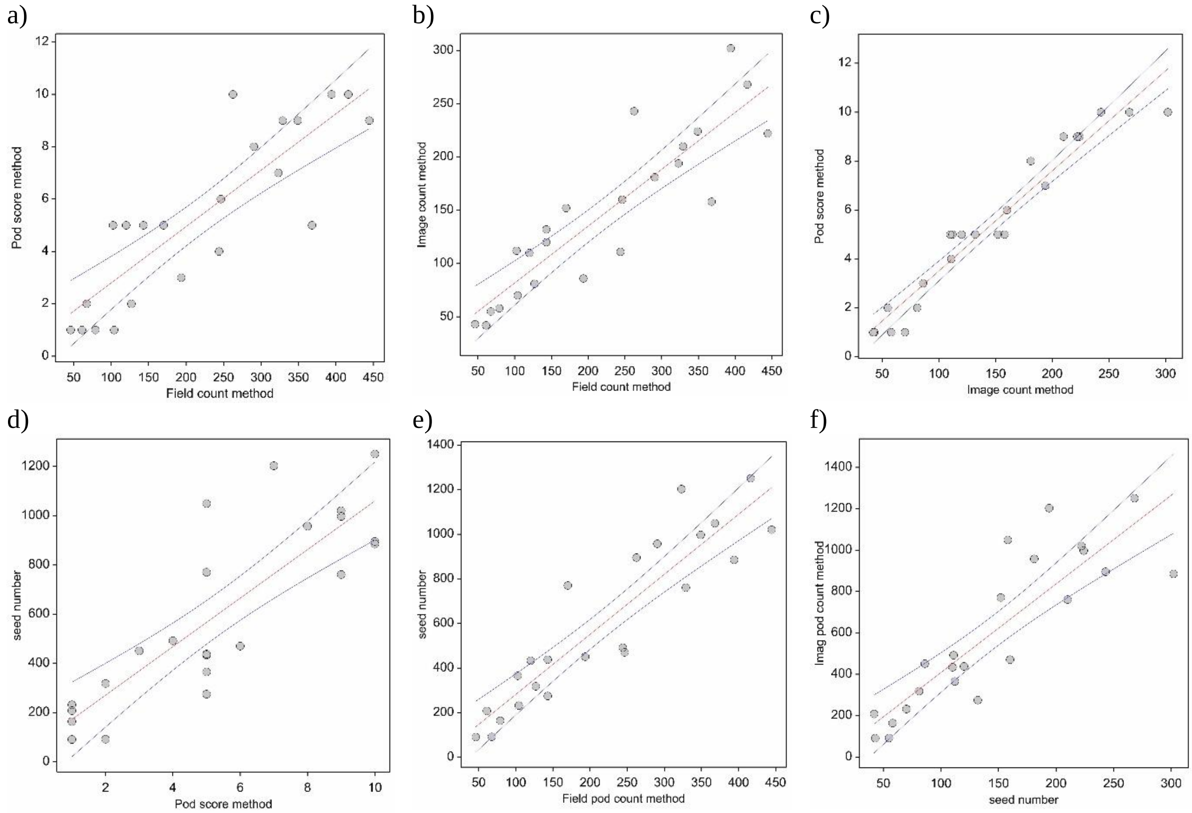

Figure 1. Comparison of pod loss method from validation plots in Experiment 1: a) pod count (PC) vs. pod loss score (PS) r^2 =0.71, b) PC method vs. image count method (IC) r^2=0.79, and c) IC vs. PS method, r^2=0.93. Comparison of surface seed (SS) counts from validation plots in Experiment 1 against: d) SS vs. PS methods y = 73.7+98.6x r^2=0.69., e) SS vs. PC methods y = 12.8+2.69x r^2=0.82, f) SS vs. IC methods y = -20 + 4.28x r^2=0.74 Red line fitted regression, blue lines 95% confidence intervals.

For the pod loss score ANOVA of all plots, for all three experiments there were significant genotype (P< 0.05) effects, but no significant (P> 0.05) phytophthora or genotype by phytophthora interaction.

For Experiment 1 the pod image count analyses of all plots also provided significant genotype (P< 0.05) effects, but no significant (P> 0.05) phytophthora or genotype by phytophthora interaction. The genotype values from the pod loss score and image count methods for Experiment 1 were highly correlated (0.907). The genotype values from ANOVA of all plot pod loss score and pod image count methods were used in conjunction with the regression equations in Figure 1 to predict the number of seed lost to the soil surface. From the number of predicted dropped seeds, the predicted weight of grain was calculated and the proportion of grain weight dropped relative to total grain, where total grain was the quadrat harvested and predicted loss (Figure 2a, b). In terms of the relative amount of grain dropped both methods showed that: the percentage of grain loss was considerable; the range among genotypes was greater than 20%; there was no trend for high yielding genotypes to have high grain losses.

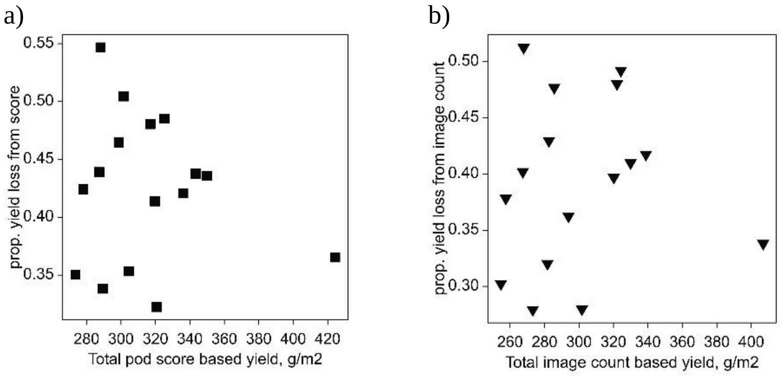

Figure 2. Experiment 1 predicted proportion of grain lost in relation to total grain for: a) pod loss score method, b) image count pod loss method.

Conclusion

We showed that a 1 to 10 scoring system could provide estimates of pod loss from which grain loss could be calculated. Counts of pods in the field or counts of pods from images were more accurate but as they were more time consuming would require more resources to obtain. The results for pod counts from images indicated that it would be useful to develop automated image assessment systems to determine pod losses. All genotypes had substantial pod loss after six weeks of delayed harvest, but there was significant variation in pod and grain loss among the desi genotypes examined. There was no evidence for high pod or grain loss being linked to high yielding genotypes, indicating that chickpea varieties can be improved through minimising pod or grain losses prior to harvest.

Acknowledgements

This research was made possible by co-funding from NSW DPI and the Grains Research and Development Corporation (GRDC) under the National Variety Trial Disease rating project and through project DAN00213, the Grains Agronomy Pathology Partnership.

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