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Abstract. Average seed weight, as determined by samples consisting of 100 seeds, was significantly correlated with yield and bushel weight in fungicide and varietal response trials. In one fungicide trial seed weight was a more sensitive measure of rust control than yield or bushel weight. In varietal trials seed weight response to the crown rust fungus of oats grown in hill plots was significantly correlated with yield response in 32-square-foot plots.

Crown rust, caused by *Puccinia coronata* Cda. var. *avenae* Fraser & Ledingham, is the most serious disease of oats in the major oat-producing areas of the world. The principal control measure has been the use of oat varieties with seedling resistance to the causal fungus. The appearance within recent years, however, of races of the fungus that attack all known sources of seedling resistance among the hexaploid oats (Simons *et al.*, 1957) has led to greater interest in field resistance and tolerance to the fungus. Field resistance and tolerance are more difficult to measure than seedling resistance and therefore quantitative methods must often be used.

Crown rust affects the total yield and quality of the grain. Yield, bushel weight, and weight of 1,000 seeds have been used to measure damage caused by the fungus. In northern states, where the majority of the oat grain is produced, the time during which the fungus can damage the crop is very short. For all practical purposes this time is limited to the interval between heading and maturity. Grafius (1956) has pointed out that oat yield per unit area can be regarded as the product of three components: number of panicles per unit area, number of seeds per panicle, and weight of the seeds. Frey and Wiggans (1957) showed that all productive tillers are initiated within a few weeks after planting, and Holt (1955) reported differentiation of the florets was completed well before heading. Consequently, the crown rust fungus, which in the northern states does not affect the plants until after heading, can affect only one of the three yield components, namely weight of the seeds. Thus weight of the seeds should furnish an adequate measure of the effect of the fungus, and it should be more precise than yield, which is influenced by variation in the other two yield components.

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The investigations described herein were undertaken to explore the usefulness of seed weight as a quantitative measure of the effect of the crown rust fungus on its host.

Materials and Methods

Unless otherwise noted, oats used in this study were grown in plots consisting of four eight-foot rows one foot apart. Data were obtained from the two center rows of each plot. Crown rust spreader rows of a highly susceptible variety separated adjacent plots. When in the jointing stage, about 10 plants in each spreader row were inoculated hypodermically with a water suspension of urediospores of common races of the crown rust fungus. The pathogen was allowed to spread naturally from the resulting centers of infection.

Results

Sample Size and Sampling Techniques. Since individual seeds on any panicle of oats vary considerably in weight, the seed weight component of yield must be regarded as average seed weight. Thus a sample from a given seed stock must be taken and used to estimate the true average seed weight. With this in mind, optimum sample size and methods of obtaining samples were considered.

The smallest sample that will give the desired results is obviously the best. The old standard of 1,000 seeds involves a great deal of counting if many lines or treatments are being tested, and requires more seeds than may be available in certain kinds of investigations. K. J. Frey and his students showed that a sample of 100 seeds was adequate for agronomic work (unpublished data). The writers' preliminary experiments, in which samples of 100 and 200 seeds were compared, indicated that the 100-seed sample was large enough. Therefore, 100-seed samples were used throughout this investigation.

A small fungicide test, consisting of five experimental fungicides and a non-treated check, in four replications, provided material suitable for comparing samples obtained in different ways. When seeds are counted by hand, there is a possibility that one person may tend to select lighter or heavier seeds than another. To test this, three people each counted at least two 100-seed samples from the seed harvested from each of the plots in the fungicide test. Examination of the weights of these samples showed that the variation among samples counted by one person was about the same as the variation among samples counted by different people. A seed divider was also used to obtain a representative sample of about the right size, from

which 100 seeds were counted. This procedure appeared to have no advantage over simply counting seeds from the bulk stock. Seeds of some species of crop plants can be counted very rapidly with the aid of mechanical devices that utilize the vacuum principle. Such a machine, borrowed from the Iowa State University Seed Laboratory, worked fairly well with high quality seed and reduced the time required for counting. The machine did not work well with poor seeds, however, and was not tried further.

An electronic seed counter, obtained after the study was initiated, provides samples as representative as those obtained by hand counting, and is much more efficacious where many samples must be counted.

Seed Weight in Comparison with Yield and Bushel Weight in Fungicide Trials. Correlation coefficients were calculated for four of the 100-seed weight determinations mentioned above with yield and with bushel weight. The four coefficients for seed weight and yield were similar and averaged 0.787. The four coefficients for seed weight and bushel weight also were similar and averaged 0.844. A single seed weight determination was made for each of the entries of a larger fungicide test that included 42 treatments. In this test the correlation coefficients for seed weight and yield were 0.560 and for seed weight and bushel weight 0.719. All these coefficients were significant at the .01 level.

Analysis of variance of yield data from the small fungicide test showed that two treatments resulted in yields significantly higher than no treatment. The remaining three treatments did not affect yield significantly. The mean square for bushel weight was not significant. The data from three seed weight determinations were analyzed, and in each case the two treatments that had resulted in increased yield also increased seed weight significantly. Seed weights were not affected by the other treatments.

Analysis of variance of yield and bushel weight data from the large fungicide test showed that several treatments resulted in significant increases. Analysis of seed weight data indicated, with a single exception, that treatments giving increased yield and test weight also resulted in increased seed weight. In addition, several treatments that did not appear to affect yield or bushel weight increased seed weight significantly.

In these fungicide tests the coefficients of variation for yield averaged about 8%; for bushel weight, about 4%; and for seed weight, about 6%.

Seed Weight as a Measure of Varietal Response to the Crown Rust Fungus. Seed weight is not satisfactory as a direct measure of varietal response to the crown rust fungus because different varieties of oats grown under comparable conditions produce seeds of different average weights when free of crown rust. The same is true, of course, for yield and bushel weight. Consequently it is necessary to use indirect methods of measurement. In these experiments a "split-plot" type of design was used, plots of each variety consisting of rusted and non-rusted halves. The fungicide zineb was applied as frequently as necessary to maintain the non-rusted halves free of rust. Response to infection, whether in terms of yield or seed weight, is then expressed as the percentage increase attributable to the fungicide, or decrease due to rust. Obviously when the rusted and non-rusted plot-halves yield about the same, the variety in question is either resistant or tolerant. If foliage of such a variety has resistant-type uredia, the variety is rated resistant; if it has susceptible-type uredia, it is rated tolerant. If the protected half yields a great deal more than the rusted, the variety is susceptible.

Twenty-five varieties, including several known to be highly resistant and several known to be very susceptible, were planted, in split plots, in four replications. The very susceptible varieties showed large percentage decreases due to rust in terms of yield, bushel weight, and seed weight. The relationships between these three measures of responses of the other varieties were not so clear-cut, but the overall correlation of yield and seed weight was 0.550 and of bushel weight and seed weight 0.743. Both correlation coefficients were significant.

One potentially useful application of seed weight in relation to response to rust infection is in reducing plot size and therefore quantity of seed necessary to carry out an experiment. In preliminary experiments plots consisting of single three-foot rows, of clumps or hills of 30 plants, and of hills of five plants were compared. The results showed that hills of plants from 30 seeds, spaced one foot apart in rows which were also one foot apart, would probably be satisfactory for seed weight determinations.

Seeds of the 25 varieties described above were planted in the same field plan as above except that hills were used, rather than four-row plots. Susceptible varieties in this experiment were more severely damaged than in the four-row plot test, but the varieties in general showed the same relative responses to infection. The correlation coefficients of percentage increase in seed weight in this test with corresponding increases in yield and in bushel weight in the four-row plot test were 0.700 and 0.502, respectively. Both coefficients were significant,

Discussion and Conclusions

Average seed weight, as determined by 100-seed samples, appears to be a suitable measure of the response of oats to the crown rust fungus. When yield is used, the effect of the fungus is in theory, confounded with factors affecting all components of yield, while the use of seed weight eliminates all these factors except those that affect seed weight. Seed-weight data from the large fungicide test discussed above showed that a number of treatments that could not be shown to affect yield significantly were actually effective in controlling the crown rust fungus. This constitutes experimental evidence that seed weight is a more precise measure of host response to crown rust than is yield.

Related studies have shown that some of the most common and important factors affecting yield have relatively little effect on the seed weight component of yield or else affect the seed weights of different varieties by the same amount (Frey 1959*a*, Frey 1959*b*). This further enhances the theoretical superiority of seed weight over yield in studying the crown rust disease.

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