FORAGE OAT VARIETIES FOR THE NORTH ISLAND WITH EMPHASIS ON DISEASE RESISTANCE

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ABSTRACT

Oats (**Avena sativa** L.) have potential for growing as a forage crop between successive silage maize crops in the North Island. The main requirements for a successful oat variety in this system were found to be tolerance to barley yellow dwarf virus and resistance to crown rust. None of the varieties that are currently available in New Zealand possessed both characters, but varieties from the southern United States were found that possessed tolerance to barley yellow dwarf virus, resistance to crown rust and had the ability to produce a high yield of forage.

INTRODUCTION

Oat crops grown for forage have had an important place in New Zealand agriculture for many years (Claridge, 1972). These crops are sown in autumn, and are grazed during periods of pasture shortage during winter and early spring. Specialist forage varieties have not been available, so dual purpose grain and forage oats (**Avena sativa** L.) have been used for forage (Claridge, 1972).

With the increased interest in maize as a silage crop in the North Island (Kerr, 1975), forage oat crops may gain a new place in New Zealand agriculture. Oat and other green-feed cereal crops have the potential to be sown after the silage maize crop is harvested, and be grazed or ensiled before the next maize crop is sown. With this in mind, we conducted experiments to identify suitable varieties to grow between successive maize crops in the North Island.

MATERIALS AND METHODS

Experiment 1

Ten varieties of oats and one variety of wheat (**Triticum aestivum** L.) were grown at Palmerston North and Kaitaia. The wheat variety was added because of its known high tolerance to barley yellow dwarf virus (Qualset **et al.**, 1973) and immunity to crown rust of oats. The soil at Palmerston North was a Manawatu fine sandy loam and at Kaitaia was a Kaitaia clay loam. A fertilizer mixture was broadcast at Palmerston North before sowing at the rate of 42 kg/ha N, 18 kg/ha P, and 49 kg/ha K, but no fertilizer was used at Kaitaia as previous experience had indicated that this experimental field was highly fertile. Sowing dates were 11th April 1975 for Palmerston North and 16th April 1975 for Kaitaia. A winter and spring harvest was taken at each location, with data collected on dry matter production and protein. The harvest dates were 25th July and 29th October at Palmerston North, and 6th July and 21st October at Kaitaia. Heading dates were recorded at Palmerston North only.

Half the plots at each location were sprayed at weekly intervals with the fungicide Zineb (zinc ethylene bisdithiocarbamate) commencing on 2nd September at Palmerston North and 11th August at Kaitaia. The fungicide was used to suppress crown rust.

The experimental design at each location was a split-split plot with whole plots arranged in a randomized complete block design with three replications. Fungicidal treatments were whole plots, harvest dates sub-plots, and varieties sub-sub plots. The sub-sub plots were six rows wide and three metres long, with 15 cm spacing between rows. Approximately 400 seeds were sown in each sub-sub plot, and the centre two rows were harvested for yield and protein evaluation.

Symptoms of barley yellow dwarf virus were scored on the plots at Palmerston North on 18th June, and the incidence of crown rust was scored on 9th September at Kaitaia. A positive identification of barley yellow dwarf virus was made by transferring aphids from plants in the field, which were suspected to be infected with the virus, onto test plants in the glasshouse and observing the occurrence of symptoms. A scale of 1 to 5 was used for barley yellow dwarf virus in the field, with 1 used to denote no symptoms and 5 to denote severe yellowing and red discolouration of all the leaves. The standard scale of 1 to 6 was used for crown rust (Kiraly **et al.**, 1970). Seedling tests for resistance to crown rust were made during the winter in a glasshouse at Palmerston North. The urediniospores of the casual agent (**Puccinia coronata** Cda. avenae Fraser and Led.) were collected from volunteer oat plants found growing near Palmerston North and near Kaitaia during the autumn of 1975. Standard technqiues for evaluation of rust resistance were used (Browder, 1971).

Experiment 2

The data for experiment 2 was extracted from the National Cool Season Forage Trials conducted by D.S.I.R., the Ministry of Agriculture and Fisheries, and Dalgety (N.Z.) Ltd. A complete report of these trials will be published elsewhere.

In brief, the experiments were sown on 16th April 1975 at several locations and with many species, but only spring data on oats from Kaitaia, Rukuhia and Palmerston North will be considered in this paper. The experimental design was a randomized complete block design with four replications at each location, and the plots were 5 m wide and 15 m long. One square metre was harvested from each plot at three-weekly intervals for yield evaluation.

RESULTS

The countries of origin and heading dates at

TABLE 1: Countries of origin, heading dates and crown rust and barley yellow dwarf virus resistance scores for oat and wheat varieties grown in 1975.

Variety	Country of origin	Heading date	Seedling crown rust	Adult Plant crown rust Kaitaia 9 Sept.	Barley yellow dwarf virus Palmerston Nth 18 June
Mapua	New Zealand	–	S	6.0	3.0
Amuri	New Zealand	15 Oct.	MS	5.0	2.0
Algerian	Unknown	1 Nov.	MS	2.5	5.0
Achilles	Canada	29 Oct.	MS	6.0	4.0
Florida AB113	U.S.A.	10 Oct.	R	0.0	2.0
Florida 501	U.S.A.	12 Oct.	R	0.0	2.0
Suregrain	U.S.A.	15 Oct.	R	1.0	2.0
Elan	U.S.A.	17 Oct.	R	0.0	2.0
Avon	Australia	21 Sept.	S	5.5	2.0
Coolabah	Australia	7 Oct.	S	5.5	2.0
Karamu	New Zealand	10 Sept.	–	–	1.5

Seedling crown rust: S = susceptible; MS = moderately susceptible; R = resistant

Adult plant crown rust: 0.0 = no crown rust to 6.0 = heavily infected

Barley yellow dwarf virus: 1.0 = no symptons to 5.0 = severe yellowing

Palmerston North for all entries are presented in Table 1. All entries, except Mapua, headed before the experiment was terminated on 2nd November.

In glasshouse tests, only the American varieties were resistant to crown rust at the seedling stage of growth (Table 1). The resistant varieties all produced hypersensitive flecking, indicating the presence of effective vertical, or race specific, resistance genes against the rust races used. These differences in seedling susceptibility were also apparent in adult plant infection rates (Table 1). Amuri, Avon and Coolabah, however, appeared to be slower rusting than Mapua and Achilles, and Algerian had fewer pustules than other susceptible varieties. These observations do not necessarily indicate physiological forms of slow rusting, such as increased latent period from inoculation to pustule appearance, because inoculation with rust spores hetereogeneous for virulence would produce a similar result.

A heavy infection with barley yellow dwarf virus occurred at Palmerston North in the late autumn. The barley yellow dwarf virus symptoms were not observed at Kaitaia. All the entries, including Karamu, which has a high level of tolerance (Qualset et al., 1973), showed symptoms of the disease, but large varietal differences were apparent with symptoms most severe on Algerian and Achilles (Table 1).

At the mid-winter harvest, Avon and Coolabah produced the highest forage yield at both locations, and the American varieties were also high yielding (Table 2). Algerian produced a very low yield of dry matter at Palmerston North, and Achilles was also low yielding at Palmerston North, but among the highest yielding varieties at Kaitaia. The low yields of Algerian and Achilles at Palmerston North were undoubtedly due to their susceptibility to barley yellow dwarf virus. The susceptibility of Algerian has been noted previously by Claridge (1972).

TABLE 2: Winter dry matter yields of the oat and wheat varieties at two sites.

Variety	Palmerston North 25 July	Kaitaia 6 July
	Yield (kg/ha)	Yield (kg/ha)
Mapua	2851	3360
Amuri	2652	3506
Algerian	689	3387
Achilles	2413	3670
Florida AB113	3218	3375
Florida 501	3006	3806
Suregrain	3066	3710
Elan	2724	3326
Avon	3370	3914
Coolabah	3465	3735
Karamu	2458	2868
l.s.d. (P = 0.05)	381	562

The mean protein contents were 17.7% at Palmerston North and 20.4% at Kaitaia at the winter harvest. All entries were similar, but the earliest heading oat variety, Avon, was lower with a protein content of 15.0% at Palmerston North and 17.2% at Kaitaia.

The spring yields of the susceptible varieties were increased by fungicidal applications in all cases except for Coolabah at Palmerston North, but no such trend was apparent for the resistant varieties (Table 3). Crown rust appeared in the plots at Kaitaia in early August, and at Palmerston North in September. Fungicidal applications were commenced at this time,

TABLE 3: Spring dry matter yields of selected oat varieties with and without fungicidal treatment at two sites.

Variety	Palmerston North 29 October		Kaitaia 21 October	
	Treated (kg/ha)	Not treated (kg/ha)	Treated (kg/ha)	Not treated (kg/ha)
Mapua	13650	11431	6263	2850
Amuri	18895	15387	6492	3232
Algerian	4638	2774	11692	6022
Achilles	16687	12311	5082	4431
Florida AB 113	19979	19983	10295	7718
Florida 501	17769	18625	7812	6965
Suregrain	17619	18064	9883	8678
Elan	16240	16057	8064	9629
Avon	18253	17895	6481	3764
Coolabah	19587	20077	6109	5709
Karamu	12014	10422	6373	8075

Least significant differences (P = 0.05)

(1) For comparing two varieties within a treatment at Palmerston North = 2336

(2) For comparing treatments within a variety at Palmerston North = 2313

(3) For comparing two varieties within a treatment at Kaitaia = 5021

(4) For comparing treatments within a variety at Kaitaia = 7662

and these reduced the rate of spread of the disease. The fungicide was more effective at Palmerston North than at Kaitaia, probably due to the lower incidence of rain at this location. Fungus diseases other than crown rust were observed at both sites, but these appeared to be of minor importance compared to crown rust.

The yield difference between the treated and untreated plots of the susceptible varieties can be taken as an indication of the yield reduction due to crown rust, but because of our inability to completely control the disease by chemical means, particularly at Kaitaia, this must be considered an approximation. Nevertheless, a yield decrease of 19% at Palmerston North and 120% at Kaitaia for Mapua, and 23% at Palmerston North and 100% at Kaitaia for Amuri illustrates the large effect natural crown rust infection can have on forage yields of oats.

A clear indication of the effect of crown rust on the growth of Mapua was obtained in the second experiment. Mapua and Florida 501 produced dry matter at similar rates until early September at Kaitaia, but then the dry matter production rate of Mapua declined and a weight loss occurred during late September and October (Fig. 1). At Rukuhia, a similar pattern emerged with Mapua and Elan, but the reduction occurred later and the experiment was terminated before any decline in dry matter yield occurred. At Palmerston North, both Mapua and Florida AB113 produced dry matter at similar rates throughout September and October. The decline in the rate of dry matter production of Mapua at Kaitaia and Rukuhia coincided with the appearance of large numbers of crown rust pustules on the leaves and the subsequent senescence of the leaves, so we feel certain it was due to crown rust alone. The onset of physiological maturity cannot be implicated because Mapua headed later than Florida 501, Florida AB113 and Elan and senescence of the leaves commenced before heading at Kaitaia.

The mean protein content of oat forage was 6.5% at Palmerston North and 6.8% at Kaitaia at the spring harvest. Crown rust did not appear to alter the protein contents at either site, and differences between varieties were small.

Amuri, Florida AB113, Florida 501, Suregrain, Avon and Coolabah produced yields of dry matter in excess of 17,000 kg/ha at Palmerston North (Table 3). The high yields of Florida 501, Suregrain, and Florida AB113 were particularly encouraging, because these varieties were tolerant of barley yellow dwarf virus and resistant to crown rust. Yields were must lower at Kaitaia and errors much higher (Table 3). This was probably due to the severe crown rust epidemic and waterlogging conditions which occurred during the spring at Kaitaia. The crown rust epidemic was implicated as an error inducing factor because resistant and susceptible varieites were grown in a randomized pattern, and this would be expected to lead to a heterogenous rate of infection across the experiment. Furthermore, the epidemic was so severe that considerable senescence of leaf material occurred on varieties such as Florida 501 that have the necrotic type of hypersensitive resistance. Because of the large errors at Kaitaia, no useful conclusions about the relative agronomic worth of the varieties can be made for this location, although Florida 501 produced almost 16,000 kg/ha in experiment 2 where the plots were larger and rust infection from neighbouring sensitive plots was slight.

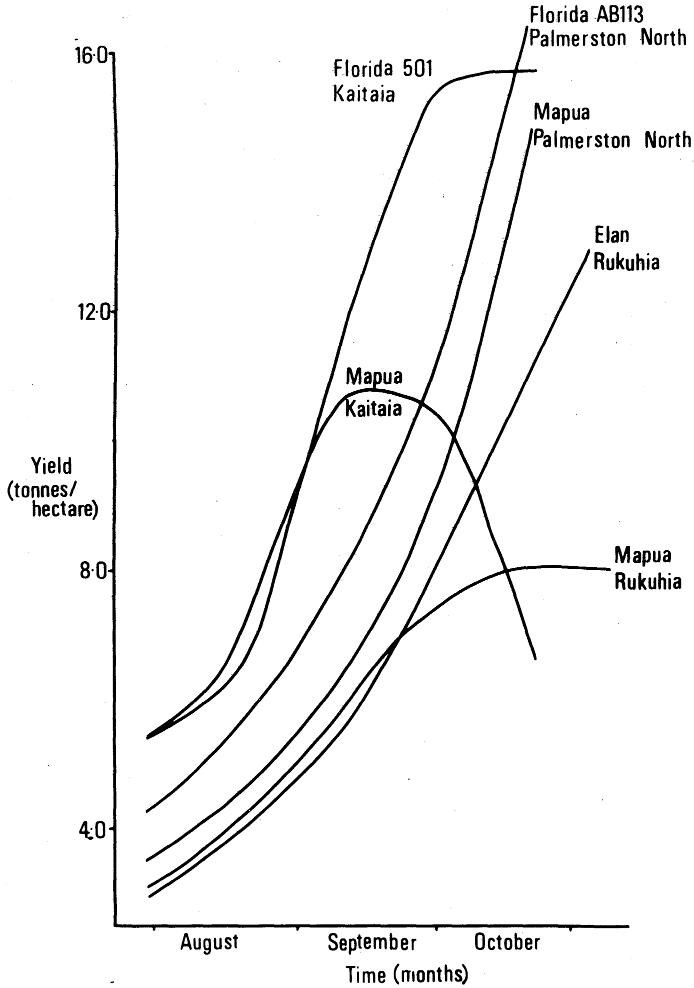

Figure 1. Spring dry matter yields of selected oat varieties at Kaitaia, Palmerston North and Rukuhia.

DISCUSSION

Two diseases, barley yellow dwarf virus and crown rust, exerted a major influence on the growth of autumn-sown oats in our experiments. Both diseases are widespread on a world scale (Rochow, 1961; Simons and Murphy, 1961) and in New Zealand (Wratt, 1956; Smith, 1963; Claridge, 1972).

Barley yellow dwarf virus severely depressed the seedling growth of susceptible varieties at Palmerston North. The frequency with which such reduction would occur for autumn-sown oats in the North Island is unknown, but Latch (1977) observed a large reservoir of virus in ryegrass pastures in the Manawatu and Northland areas, and Close (1970) found yield reductions due to barley yellow dwarf virus to be common in spring-sown wheat in the North Island. Thus, reductions in forage yield due to barley yellow dwarf virus might be common and therefore highly susceptible varieties, such as Algerian, must not be recommended for forage production and all new varieties should be tested for tolerance to barley yellow dwarf virus before release.

Crown rust reduced forage yields during the late winter and early spring, especially at Kaitaia and Rukuhia where temperatures were higher during this period. None of the varieties that were available in New Zealand, and were in our experiments, were resistant to this disease. Amuri was considered resistant when originally released (Milne and Wright, 1969), but races of **Puccinia coronata** which are virulent on Amuri are now widespread in New Zealand (Martens, personal communication). In fact, Martens found all currently available varieties to be susceptible to some of the races of **Puccinia coronata** in New Zealand.

The release of one of the American oat varieties tested in our experiments would provide a crown rust resistant forage oat for New Zealand farmers. Such a release, however, would only provide a short term solution to the crown rust problem, because **Puccinia coronata** is highly variable and the widespread cultivation of a variety with a new resistance gene inevitably has led to a shift in the fungal population towards virulence on the new variety (Browning and Frey, 1969). The length of time between releases and the widespread occurrence of the disease on the new variety determines its effective life in rust-liable areas. The life of one of these varieties in New Zealand is unknown, but from North American experience could be as short as 3 years or as long as 20 years.

The American varieties in our experiments were adapted to the states bordering the Gulf of Mexico. New varieties, carrying different resistance genes, have been released for this area (McDaniel, 1974) and these would provide replacements for the varieties in our experiments if shifts in the pathogen population made replacement desirable. These new varieties were found to be resistant to the prevalent races of crown rust in New Zealand (Eagles, unpublished data) and are being tested for forage production potential.

Another method for providing a crown-rust resistant variety would be to backcross new resistance genes into a dual purpose grain and forage variety which has already been accepted by farmers in New Zealand. At least five resistance genes would be suitable for this purpose (Martens, personal communication; Eagles, unpublished data) and we have now commenced a programme to backcross two of these genes, Pc-36 and Pc-51, from the Iowa isolines C.I. 9170 and C.I. 9181 (Frey and Browning, 1973), into Avon and Amuri. At the completion of this programme we should have versions of these varieties which carry two or three resistance genes (Amuri carries the "Victoria" gene already) in genetic backgrounds which may have some horizontal resistance. This combination should greatly extend the useful life of these varieties compared to the release of a variety with a single resistance gene (Van der Plank, 1968; Watson, 1970; Nelson, 1972).

Forage yields in excess of 17,000 kg/ha obtained from disease-resistant oat varieties at Palmerston North and almost 16,000 kg/ha from Florida 501 in large plots at Kaitaia were encouraging, particularly when compared to yields obtained from Mapua in our study and by other workers (Davies and Neilson, 1975; Kerr and Menalda, 1976). The striking deficiency of all varieties, however, was the low average protein concentration of 6 to 7% in forage from the spring harvest. The minimum level of 12% protein necessary for lactating dairy cows (Anon, 1971) was not reached by any of the varieties. The potential for breeding new cultivars with higher forage protein has only recently been investigated in oats, mainly by Campbell and Frey (1974) and Frey, McCarty and Rosielle (1975), who found wild relatives of the cultivated oat with straw protein as high as 12% at maturity and groat protein exceeding 30%.

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