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EFFECTS OF RUST ON GROWTH AND YIELD OF SUNFLOWER IN AUSTRALIA

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Since 1970 there has been a marked increase in the area sown to sunflower in Australia and it is likely that sunflower will continue to be an important oilseed crop in the future. As a results of the increased importance of the sunflower industry, there has been an increasing awareness as to the role plant diseases might play in limiting economic returns from the crop.

During 1972 the authors commenced detailed surveys of sunflower diseases in Northern New South Wales and Southern Queensland. This survey showed that rust caused by *Puccinia helianthi* Schw., white blister caused by *Albugo tragopogonis* Pers. ex S.F. Gray and charcoal stem rot caused by *Macrophomina phaseoli* (Maub.) Ashby were the most common and widespread diseases during the period 1972—1974. Of these diseases rust appeared to cause greatest loss of yield. Sclerotinia head rot caused by *Sclerotinia sclerotiorum* (Lib.) de By and head rots from which *Rhizopus* sp. *Alternaria* sp. and *Botrytis* sp. were isolated were common in some fields but were not considered to be of major economic importance to the industry as a whole. Similarly, basal stem rot caused by *S. sclerotiorum* and root rots from which *Fusarium* sp. were isolated as well as a leaf spot caused by *Septoria helianthi* Ellias and Kellerman were observed in isolated fields. In addition to these diseases, Allen (1972) considered Verticillium wilt *(Verticillium dahliae* Kleb.) Fusarium wilt *(Fusarium oxysporum* Schlecht) and bacterial wilt *(Pseudomonas solonacearum* E. F. Smith) to cause serious damage to individual plants but to be uncommon diseases of sunflower in Australia. Other diseases reported by Allen (1972) included Powdery mildew *(Erysiphe cichoracearum* D.C. ex Merat), Cercospora leaf spot *(Cercospora* sp.), stem rot associated with the presence of *Phomopsis* sp. damping-of from which *Plythium* sp. was isolated, greying of the petiole associated with what appeared to be *A. tragopogonis* and a snapping of the stem below the head caused by unknown factors. Many of the reports made by Allen (1972) have not yet been confirmed.

Alcorn and Pont (1972) reported a leaf spot caused by *Alternaria helianthi* (Hansf.) Tubaki in Northern Queensland. Downy mildew caused by *Plasmopara helstedii* (Farl.) Berl. and Toni has not been observed in Australia and rigid quarantine regulations have been evoked in an attempt to prevent its introduction.

Few attempts have been made to accurately assess the relative importance of various diseases of sunflower. Rust is usually regarded as being the most important disease of sunflower and has been reported to have caused serious losses of yield in Argentina (Muntanola, 1955), Canada (Putt and Sackston, 1955) and Russia (Efremova and Karakul in 1929). United States workers however consider rust to be of minor importance (Culp and Kinman, 1965; Robinson, Johnson and Soine, 1967). Middeleton and Obst (1972) found that a natural rust epidemic in southern Queensland caused major losses of yield. They showed that the regular application of Maneb as a foliage fungicide to control rust resulted in yield increases of 71 percent (kg/oil/ha) over that observed in unsprayed control plots. Similarly, Kurnik and Meszaros (1962) reported that the use of Zineb resulted in yield increases of 22.2 percent in experiments undertaken in Hungary. It would seem therefore that, at least in some environments, rust is potentially capable of causing major reductions of yield.

The purpose of the study reported in this paper was twofold. Firstly, field trials were undertaken in the Gwydir Valley of New South Wales to investigate the effects of natural epidemics of rust on sunflower yields and to determine the effects of delaying the onest of an epidemic on sunflower yields. A second series of greenhouse trials were made to study the effects of rust infection of three different intensities and of the presence of rust infection of different durations of time on growth and yield parameters of sunflower.

EXPERIMENTAL

1. *Effect of a natural epidemic of rust on sunflower yield — 1972 irrigated field trial.* An irrigated field trial (cv. Peredovik) was hand sown on 24 February, 1972 in rows 15 m long and 76 cm apart at the rate of 74,000 plants/ha. At 5 weeks after sowing twenty different foliage spray schedules were commenced to control rust. Four fungicides and five spray schedules of each fungicide were used. The fungicides used were :

(1) Mancozeb, 85 percent active ingredient at 200 g/100 l ; (2) Maneb, 53 percent active ingredient plus 19 percent nickel sulphate at 300 g/100 l ; (3) Benomyl, 50 percent active ingredient at 25 g/100 l and ; (4) Carboxin, 75 percent active ingredient at 25 g/100 l. The five spray schedules used in this trial were : (1) unsprayed control ; (2) sprayed once at 5 weeks after sowing ; (3) sprayed three times at 5, 7 and 9 weeks after sowing ; (4) sprayed five times at 5, 7, 9, 11 and 13 weeks after sowing and ; (5) sprayed seven times at 5, 7, 9, 11, 13, 15 and 17

weeks after sowing. The trial was designed according to a randomized, splitplot design consisting of three replicates. Each plot consisted of three rows and only the central 9 m of the central row was assessed and harvested in the trial. The outer two rows in each plot served as buffer rows.

Rust assessments were made at two-weekly intervals using a field assessment key based on the percentage of the leaf area covered with rust pustules. Ten plants were randomly selected in each plot and rust assessements were made on each photosynthetically active leaf of each plant. The rust assessment for each plant was obtained by summing the assessment for each leaf and dividing by the total number of leaves assessed.

The trial was hand harvested on 18 May, 1972 and the head diameter, thousand seed weight of clean dried seed, percentage oil content (nuclear magnetic resonance method) and weight of seed harvested per 9 m of row was determined. An estimate of the seed yield (kg/ha) and oil yield (kg/ha) was then calculated.

The data are shown in table 1. The incidence of rust on the unsprayed control plots varied from about 11 to 15 percent (mean 11.4 percent) during the post-flowering stages of plant growth. Mancozeb and Maneb plus nikel sulphate were effective in controlling rust, carboxin gave partial control of rust and Benomyl was ineffective against the fungus at the rates used in this trial. The application of Mancozeb at regular intervals reduced the incidence of rust from 11.4 percent to 3.4 percent at the post flowering stages of plant growth. This reduction in rust incidence was associated with an estimated 76 percent increase of yield (kg/oil/ha).

Table 1

Effect of four fungicides on rust development and on yield parameters of sunflower in the Gwydir valley of New South Wales

Fungicide	Rust assessment (%)	Head diameter (cm)	Thousand seed weight (g)	Oil content (%)	Estimated seed yield (kg/ha)	Estimated oil yield (kg/ha)	Oil yield increase over control (%)
Control (unsprayed)	11.4	9.9	35.9	43.6	1111.9	486.5	0
Mancozeb	3.4	11.4	42.4	45.0	1904.4	857.0	76
Maneb + Nickel Sulphate	3.8	11.0	40.5	46.0	1543.1	711.4	46
Carboxin	6.6	10.1	37.9	44.2	1428.7	631.5	30
Benomyl	10.1	10.1	37.8	42.7	1195.7	510.6	5
L.S.D. P = 0.05		0.74	5.59	2.27	439.35	223.81	
L.S.D. P = 0.10		0.59	4.50	1.83	354.37	180.52	

As a result of the various spray schedules used, it was possible to obtain a range of levels of rust infection at various stages of plant growth. Regression analysis of the data enabled calculations to be made between the rust assessment in each plot (irrespective of the fungicidal spray treatment) and the various yield components. It was found that the best correlation between the severity of rust reductions of yield parameters occurred when rust was assessed at the late flowering stages of plant growth.

2. *Effect of a natural epidemic of rust on sunflower yield — 1973 non-irrigated field trial.* Three pairs of plots, each consisting of 11 rows of 20 m length were marked within a commercial sunflower crop growing under non-irrigated conditions and which had been sown on 25 February, 1973. The crop had been sown with a row spacing of 36 cm and at a density of about 90,000 plants/ha. Half of the plots were sprayed thoroughly with Mancozeb (200 g/100 l) on 23 March, 7 April, 20 April, 5 May and 20 May. The unsprayed plots served as controls. The incidence of disease was assessed in the same way as in the 1972 trial. The plots were harvested on 15 June, 1973 to measure various yield parameters.

The data presented in table 2 show that the application of Mancozeb resulted in a significant (P = 0.05) reduction in the incidence of rust at the flowering stage of growth from 18.7 percent to 7.96 percent. This reduction in rust incidence was associated with a 23.2 percent increase in head diameter, a 28.6 percent increase in thousand seed weight and a 3.2 percent increase in the percentage oil content. The estimated oil yield was increased by 74.4 percent by the application of Mancozeb.

Table 2

Effects of rust on yield parameters of sunflower grown under irrigated and non-irrigated conditions in the Gwydir valley during 1973 season

Yield parameters	Irrigated trial			Dry land crop			
	Unsprayed control	Sprayed with Mancozeb	L.S.D. P = 0.05	Unsprayed control	Sprayed with Mancozeb	L.S.D. P = 0.05 P = 0.10	% increase
Rust assessment(%)	4,43	3.48	—	18.7	7.96	—	—
Head diameter (cm)	15.2	16.7	3.07	7.3	9.0	1.61	23.2
Thousand seed wt. (g)	53.3	61.1	4.32	26.6	34.2	7.01	28.6
Oil content (%)	48.47	48.80	2.11	42.60	43.96	0.38	3.2
Estimated seed yield (kg/ha)	2017.0	1939.2	314.2	587.5	989.9	519.63 (352.62)	68.4 68.4
Estimated oil yield (kg/ha)	976.7	944.6	139.37	253.4	441.9	268.60 (182.27)	74.4

3. *Effect of Mancozeb on sunflower yield — 1973 field trial.* An irrigated field trial was sown on 23 January, 1973. Plants were sown in rows 76 cm apart and were thinned at 4 weeks after sowing to give a population density of 74,000 plants/ha. The trial was arranged according

to a randomized block design consisting of three replicates. Eight Mancozeb spray schedules (200 q/100 l) were used in the experiment to enable rust epidemics to develop at different stages during plant growth.

From table 2 it can be seen that a rust epidemic failed to develop in the trial, due probably to environmental conditions, and the level of rust infection rarely exceeded 4 percent in any of the treatments. Moreover, the application of Mancozeb did not cause any significant ($P = 0.05$) changes in yield parameters relative to those observed in unsprayed controls. This indicates that the effect of Mancozeb on yield parameters was due to control of rust rather than throught any direct effect on plant growth.

4. *Effect of rust infection of different intensities on the growth of sunflower — 1973 greenhouse trial.* Plastic pots (15 cm diameter) containing one sunflower plant were contained within a greenhouse. The plants were divided into four groups each consisting of 20 plants. To simulate rust epidemics of different intensities, the entire photosynthetic surface of plants in the different groups were inoculated at different intervals of time commencing at 25 days after sowing. One group was inoculated at 10 day intervals, a second at 20 day intervals and a third at 40 day intervals. The fourth group was not inoculated and served as a control. The treatments provided plants which were heavily infected, moderately infected, lightly infected and uninfected throughout their growth. The plants were harvested when they were mature and the dry weight of the stem, roots and grain as well as the number of inflorescence bracts, florets and grain present on each head was determined.

From table 3 it can be seen that the total dry weight of infected plants was less than that of healthy plants. Moreover, the reduction in dry weight was related to the intensity of rust infection to which plants were exposed. The loss of stem dry weight resulting from rust infection was the main factor contributing towards the overall los in total dry weight of infected plants. Rust infection had a marked effect on the dry weight of roots. The roots of heavily, moderately and lightly infected plants was 80.4, 69.7 and 63.3 percent less that of uninfected plants.

The dry weight of seed produced per head was 74.4, 61.5 and 51.0 percent less on heavily, moderately and lightly infected plants respectively than on the uninfected controls. This reduction was related to a reduction in the number of seeds produced per head and in the weight of individual seeds. The number of inflorescence bracts and florets in infected plants was less than in uninfected plants.

In a group of plants which were harvested at 60 days after sowing (budding stage of growth) it was found that the leaf area and dry weight of leaves of heavily infected plants was over 50 percent less than that of uninfected plants.

5. *Effect of the duration of rust infection on growth and yield of sunflower — 1974 greenhouse trial.* Plastic pots containing one sunflower plant were divided into four groups each consisting of 15 plants. One group of plants was initially inoculated at 25 days after sowing

Table 3

Effect of three levels of rust infection on growth and yield parameters of sunflower grown under greenhouse conditions (mean of 20 replicate plants)

Parameter	Uninfected controls	Lightly infected	Moderately infected	Heavily infected
Stem dryweight (g)	8.5430	4.7734	3.9558	3.2782
Percentage loss		44.2	53.7	61.7
Root dryweight (g)	1.5546	0.5712	0.4719	0.3056
Percentage loss		63.3	69.7	80.4
Seed dryweight (g)	4.0636	1.9935	1.5658	1.0431
Percentage loss		51.0	61.5	74.4
Total dryweight (g)	14.1612	7.3381	5.9935	4.6269
Percentage loss		48.2	57.7	67.4
No. inflorescence bracts/head	37	32	30	31
Percentage loss		13.5	18.9	16.2
No. florets/head	361	233	229	214
Percentage loss		35.3	36.4	40.8
No. seed/head	118	74	64	51
Percentage loss		37.3	45.8	56.8

(seedling stage of growth), a second at 45 days after sowing (budding stage of growth) and a third at 70 days after sowing (flowering stage of growth). The fourth group was not inoculated and served as a control. After the initial inoculation, the leaves that subsequently formed were inoculated at 15 day intervals. The treatments provided 'simulated' epidemics which commenced at different times during growth of the plant.

From table 4 it can be seen that plants which were initially inoculated at the seedling stage of growth were affected most by rust

Table 4

Effect of the duration of rust infection on growth and yield parameters of sunflower grown under glasshouse conditions (mean of 15 replicate plants)

Parameter	Uninfected control	Infected from flowering stage to maturity	Infected from budding stage to maturity	Infected from seedling stage to maturity
Stem dryweight (g)	5.5663	5.5036	4.9913	3.9873
Percentage loss		1.2	10.4	28.4
Root dryweight (g)	0.8803	0.8052	0.6086	0.4145
Percentage loss		8.6	30.9	53.0
Seed dryweight (g)	4.1706	2.7517	1.5579	1.3939
Percentage loss		34.1	62.7	66.6
Total dryweight (g)	10.6172	9.0605	7.1678	5.7957
Percentage loss		14.7	32.5	45.4
No. florets/head	309	306	260	212
Percentage loss		1.0	15.8	31.3
No. seed/head	127	122	75	64
Percentage loss		4.0	41	49.7

infection. Plants in which the epidemic commenced at the flowering stage of growth were less affected than those which were exposed to rust from the seedling stage onwards.

DISCUSSION

The results reported in this paper indicate that rust is a major factor in limiting the oil yield of sunflower in Australia. The magnitude of losses (71 percent) reported by Middleton and Obst (1972) are similar to those reported in this paper. However, as seen from the data of trial 3 reported in this paper, rust epidemics do not always develop in all locations or during every season. During the 1974 season, field surveys showed that the intensity of the rust epidemic in Northern New South Wales was much less than that which occurred during the 1972 season. Moreover, crops that are sown late in a season usually show a higer incidence of rust than those which are sown early. Consequently, some degree of disease escape might be expected in early crops. The development of rust epidemics is dependent on their being sufficient urediospores to cause infection and on suitable environmental conditions to enable the infection process to proceed. The amount of spores available for infection is related to the level of infection in adjacent crops and the environment. In general the rust assessment at two weeks after heavy rain is low due presumably to spores being washed from leaves and out of the air. Sood and Sackston (1972) found that the environmental requirements for infection varied among races of *P. helianthi* but that the optimal temperature for germination and appressorial formation was 10 to 25°C and that penetration occurred best at temperatures of between 15 and 25°C depending on the race. Germination, appressorial formation and penetration were adversely affected by the application of light. Kajornchaiyakul (1972) obtained similar results for an Australian isolate of *P. helianthi*. Free moisture, provided by either dew or rain, is necessary for infection by *P. helianthi*.

The greenhouse studies reported in this paper suggest that the effects of rust infection on the growth and yield of sunflower is related to the intensity of the epidemic and the duration over which it is present. Simulated epidemic commencing at the early stages of plant growth (seedling and budding stage) had a greater effect on growth and yield parameters than a similar epidemic which commenced at the flowering stage of plant growth. Moreover, the deleterious effect of rust on growth and yield parameters increased with the intensity of the epidemic. One might expect therefore, that it may be necessary to assess rust incidence at different stages of plant growth in order to obtain a relationship between rust incidence and loss of yield. Under natural conditions rust epidemics rarely develop in seedling plants and are usually most prevalent during the post-flowering stages of development. Thus the data obtained in the glasshouse trials may not be directly applicable to the field situation.

The most practicable way of reducing the losses caused by rust in Australia is by the use of resistent cultivars which, at present, are unavailable commercially. It is believed however that rust resistant hybrids will be released in the near future. Some degree of rust control might also be achieved by sowing crops early in the season.

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LITERATURE CITED

1. Alcorn, J. L. and Pont, W., 1972, *Alternaria helianthi on sunflower*, Australian Plant Pathology Society Newsletter 1, 30.
2. Allen, S. J., 1972, *Diseases of sunflower in northern New South Wales*, B. Sc. (Hons.) Thesis, Department of Botany. University of New England, Armidale. pp. 98.
3. Culp, T. W. and Kinman, M. L., 1965, *Rust on sunflower in the Mississippi Delta*, Plant Disease Reporter 49, 433—434.
4. Efremova, A. M. and Karakulin, B. P., 1929, *Observations on the sunflower rust at the lower Volga Regional Agricultural Experiment Station* (in Russian), Morbi Plantarum, Leningrad 18, p. 11—30 (cited in Review of Applied Mycology 8, 791—792).
5. Kajornchaiyakul, P., 1972, *Factors affecting the infection of sunflower by Puccinia helianthi Schw.*, M. Sc. (Preliminary) Thesis, Department of Botany, University of New England, Armidale. pp. 72.
6. Kurnik, E. and Meszaros, L., 1972, *Results of spray tests against sunflower rust (Puccinia helianthi)*, (in German), Pflanzenschutzberichte, Wein 28, 47—60 (cited in Review of applied Mycology 42, 27).
7. Middleton, K. J. and Obst, N. R., 1972, *Sunflower rust reduces yield*, Australian Plant Pathology Society Newsletter 1, 18.
8. Muntanola, M., 1954, *On the presence of sunflower rust (Puccinia helianthi Schw.)*, (in spanish). Rev. agron. Noroeste Argent. 1, 213—215. (Cited in Review of applied Mycology 34, 789).
9. Putt, E. D. and Sackston, W. E., 1959, *Rust resistance in sunflower*, Nature, London 176, 77.
10. Robinson, R. G., Johnson, F. K. and Soine, O. C., 1967, *The sunflower crop in Minnesota*, Minnesota. Ext. Bull. 299.
11. Sood, P. N. and Sackston, W. E., 1972, *Studies on sunflower rust*, XI. Effect of temperature and light on germination and infection of sunflowers by *Puccinia helianthi*. Canadian Journal of Botany 50, 1879—1886.