21·8·85

CEREAL RUSTS BULLETIN

VOLUME 13 PART 1 1985

EDITED BY N. H. CHAMBERLAIN

PUBLISHED BY
THE EUROPEAN MEDITERRANEAN CEREAL RUSTS FOUNDATION

Cereal Rusts Bulletin Vol. 13, Part 1, 1985

CONTENTS

Cereal Rusts Bulletin Vol.13, Part 1, 1985

CEREAL RUSTS, DOGS AND STARS IN ANTIQUITY*

BY

J. C. ZADOKS

Laboratory of Phytopathology, Wageningen, The Netherlands

In classical Rome the rust numen Robigo was appeased by a feast, the Robigalia, held on 25 April. Ovid's description relates the dog sacrifice to Robigo with the Dog-star, unconvincingly and with an erroneous timing of events. The timing of events is confirmed by old references and modern data. The inconsistency can be explained and a consistent timing given using astronomical information. Ancient and present-day wheat and rust phenology are probably not very different. Archeological evidence for a Robigo cult has been found. The Robigalia are part of a nearly three thousand year old farmers' tradition to invoke heavenly blessings over the cereal crops.

Several authors discussed the Robigalia of ancient Rome, a ceremony intended to ward off the cereal rust (e.g. Chester, 1946; Eriksson and Henning, 1896; Sibilia, 1957). These writers and other discussions are repetitive and uncritical and moreover, they provided no new facts.

The following paper is an attempt to re-examine the available data. They belong to different categories: (1) writings of classical authors; (2) data on crop phenology; (3) data on rust phenology; (4) astronomical information; and (5) archeological findings. Together, they help us to reconstruct what happened some two thousand years ago.

Classical Sources

Outbreaks of cereal rusts were such disastrous occurrences for the farmers of antiquity that several Roman authors mentioned them (Columella, Ovid, Plinius Secundus the elder, Varro). Ovid in his Fasti (rv, 905 ff) describes the details of a procession in Rome. He records the chants of the priest not in the traditional words of the farmers but in the fashionable verse appreciated by his literate public. In the translation by Frazer (1967) I have retained the word Robigo instead of the erroneously used Mildew. The pun on rust on crops and iron is significant.

"On that day, as I was returning from Nomentum to Rome, a white-robed crowd blocked the middle of the road. A flamen was on his way to the grove of ancient Robigo to throw the entrails of a dog and the entrails of a sheep into the flames. Straightaway I went up to him to inform myself of the rite. Thy flamen, O Quirinus, pronounced these words: 'Thou scaly Robigo, spare the sprouting corn, and let the smooth top quiver on the surface of the ground. O let

---

* Original publication in honour of Professor A L Bronquinho d'Oliveira, in Garcia de Orta, Ser Estacao, Agronomica (Lisboa) q (1982) 13-20.

the crops, nursed by the heaven's propitious stars, grow till they are ripe for the sickle. No feeble power is thine: the corn on which thou hast set thy mark, the sad husbandman gives up for lost. Nor winds, nor showers, nor glistening frost, that nips the sallow corn, harm it so much as when the sun warms the wet stalks; then, dread goddess, is the hour to wreak thy wrath. O spare, I pray, and take thy scabby hands from off the harvest! Harm not the tilth; 'tis enough that thou hast the power to harm. Grip not the tender crops, but rather grip the hard iron. Forestall the destroyer. Better that thou shouldst gnaw at swords and baneful weapons. There is no need of them: the world is at peace ..... but let rust defile the arms, and when one essays to draw the sword from the scabbard, let him feel it stick from long disuse. But do not thou profane the corn, and ever may the husbandman be able to pay his vows to thee in thine absence'. So he spoke. On his right hand hung a napkin with a loose nap, and he had a bowl of wine and a casket of incense. The incense, and wine, and sheep's guts, and the foul entrails of a filthy dog, he put upon the hearth - we saw him do it. Then to me he said, 'Thou askest why an unwonted victim is assigned to these rites?' Indeed, I had asked the question. 'Learn the cause,' the flamen said. 'There is a Dog (they call it the Icarian dog), and when that constellation rises the earth is parched and dry, and the crop ripens too soon. This dog is put on the altar instead of the starry dog, and the only reason for killing him is his name.'"

This festival of the Robigalia is recorded under the twenty-fifth of April by various Roman calendars, a date a few days at variance with the one Ovid quotes for his encounter. One calendar, the Praenestine, gives some additional information: 'The festival of Robigus takes place at the fifth milestone on the Via Claudia, lest Robigo should harm the corn. A sacrifice is offered and games are held by runners both men and boys.'

Columella described the offered dog as a sucking pup. Its blood and bowels served to propitiate goddess Robigo. Confusion arises because of another dog sacrifice, meant to appease the scourging summer heat personified in Sirius, the Dog-star. The annual sacrum canarium of Doggy Sacrifice was not offered when Sirius rose as a morning star, in August, marking the blazingly hot summer period. The priests observed a rule to take the omens from dogs on a day before the corn has sprouted from the sheath, but not before it is in the sheath', apparently the late boot stage attained at the end of April or in early May. It seems plausible that the priests used the dogs of the sacrum canarium for their omens. If so, the Doggy Sacrifice was a movable feast, whereas the Robigalia took place at a fixed time. They could coincide, and thus two originally different traditions may have merged.

Robigo or Robigus originally was a numen, a spirit or abstract notion, neither male nor female. Numina, and also genii, were commonly worshipped. To appease the numen in good time, a ceremony was oranized, the Robigalia. Pliny (Book XVIII, LXIX 284-287) stated that the feast of the Robigalia was established by the Roman King Numa Pompilius (715-672 B.C.) around 700 B.C. In doing so, he possibly formalized a much older tradition. In Ovid's time (43 B.C.-A.D. 17) the Robigalia were apparently a folkloristic event for townspeople rather than a religious ceremony for peasants. The Robigalia became part of a sequence of rural festivities, the Cerealia (April 12 to 19), the Robigalia (April 25), and the Floralia (April 28).

The Cerealia also possess an element for exorcizing the rust numen. A fox with burning torches bound to his tail was chased through the stadium on April 19. Ovid (Fasti IV, 911-932) gave a folkloristic description and explanation. The red colour of the fox and the burning can be seen as references to the rusts, and the function as reminder of a lost ceremony to appease the rust numen.

Leaving aside the intricate discussion of female and male, the goddess Robigo causing the rust and the god Robigus expected to control it, a discussion irrelevant to our purpose, we pass to more recent times. The Christian Fathers Tertullian, Lactantius, and Augustine referred to Robigo (female). When Emperor Constantine made Christianity the State Religion in A.D. 323, the Robigalia remained in the calendar. Pope Gregory I (A.D. 540-604) in A.D. 598 replaced the Robigalia by the Festium S. Marci Evangelista, still on April 25. The christianized procession (which should never be postponed, according to a 1756 missal) followed the old route north along the Via Flavinia (the later and present name of the first part of the Via Claudia), passed the Ponte Milvio, and then returned to St. Peter's to celebrate mass. April 25 and the three days preceding Ascension were called Rogation Days. Processions went out into the fields, invoking the benediction of the crop. On April 25 the Litaniae Majores (major litanies) were sung. These contain vocations to Saints, prayers and supplications (rogationes). A major rogation is: Ut fructus terrae dare et conservare digneris (that You deign to give and preserve the fruits of the earth). It is the only rogation repeated thrice (Verbruggen, 1957). On the other rogation days the Litaniae Minores sufficed, a shortened version with the rogation Ut frutus terrae dare et conservare digneris, te rogamus, audi nos, without repetition. Until recently, the Rogation Days including 25 April were observed in many parts of Western Europe, including the Netherlands (Goossen, 1980; personal communications). At present, the Litaniae Majores are no longer sung except in Rome, and since 1978 the Rogation Days are no longer prescribed by the Missale Romanum. A tradition, nearly three millenia old has vanished.

Note that the Rogation Days, as so many religious and folkloristic feasts, are a reminisence of various traditions. Processions through the fields in the spring formed part of Gallic and Germanic traditions. They have been christianized, at different places and for different reasons, between the fourth and ninth centuries A.D. In the Netherlands, the protestant version is a day of prayer for the crops, on the second Wednesday in March, observed to this very day.

Crop Phenology

Wheat (Triticum aestivum) and barley (Hordeum vulgare) were the important cereals of antiquity. Pliny's remark (XVIII, XLV, 161) rubigo maxima segetum pestis (rust, the greatest pest of crops) indicates that our concern is the rust(s). The word robigo and rubigo, according to Pliny derived from rufus or red, has obviously been used in a wider sense than rust only, as it was also found on grape vines (Pliny, XVIII, XLIV 154): caeleste frugum vinearumque malum nullo minus noxium est rubigo. (One of the most harmful climatic diseases of corn crops and vines is rust). Though rusts on grape vines do exist, they did not occur in Europe and certainly not in antiquity (Roger, 1951-55). Therefore, we restrict its meaning to rust on cereals, and on wheat in particular.

I could not find any data on wheat phenology from antiquity. As there is no evidence that the climate changed considerably in the area around Rome between 500 B.C. and the present day, more recent data can be used. Yields were not different from 20th Century yields without modern inputs like improved seeds, fertilizers, and irrigation (White, 1963).

One of the oldest agricultural calendars is that in De agricultura vulgare (On Common Agriculture), written by Piero de Crescientio (1511), a judge born in 1230. Since Crescientio was a citizen of Bologna, a town at the southern edge of the Po valley, it may be assumed that this calendar applied mainly to northern Italy. He differentiated between cold, normal and warm places. As Bologna is over 250 km north of Rome, the data for warm places will be considered to represent roughly the conditions in Latium, the wheat-growing area near Rome. The following are abstracts from Crescientio's calendar (Book XII):

November - Best period for sowing wheat in warm places.

February/March - Period for weeding the cereal crops.

May - Flowering period.

June - Early June is the harvest period of barley; in warm places, the wheat harvest is completed towards the end of June.

These data are corroborated by the isophanes of wheat harvests published by Azzi (1930), by data published by Broekhuizen (1969) in the Agro-ecological Atlas of Cereal Growing in Europe (seeding - November, heading - April II and III, flowering - April III and May I, harvest III, flowering - April III and May I, harvest - June), and by recent data from the International Yellow Rust Trials - Billard (1928) and Stevens (1942) stated that the harvest took place in June, or in early July. Caution is recommended because Italian wheat breeding during the last fifty years has aimed at early harvests in order to avoid the black rust. Azzi's data, therefore, are more relevant to the present purpose than information of later date. Tozzetti (1952) confirmed that in 1767 late crops were more severely damaged than early ones.

Rust Phenology

The wheat rusts are Puccinia striiformis, P.

recondita, and P. graminis. In all probability these three wheat rusts occurred in the ancient fields as they do in modern times. In recent times, rusts appear near mid-April, according to data from rust interception trials near Rome (table 1). Yellow rust (P. striiformis) appears early in the area of Rome, but it remains insignificant. Brown rust (P. recondita) appears somewhat later, can become rather serious, but is seldom devastating. Black rust (P. graminis) usually comes last. It is difficult for the layman to distinguish between the three rust species, and presumably this also applied to ancient farmers. I feel that when the word rust (robigo) is used in classical texts, we should think mainly of black rust.

Neither in classical nor in mediaeval texts is reference made to severe rust epidemics devastating the wheat crops. In authoritative books on economic history like Postan (1966) and Slicher van Bath (1960), no diseases of wheat are mentioned. Nevertheless, there is little reason to believe that wheat rust epidemiology in antiquity was essentially different from what is seen today. The order of appearance of the three rusts will not have changed. There may, however, be differences between now and then concerning the time of appearance and the quantity of the primary inoculum of black rust. Barberry bushes (Berberis vulgaris) were probably more frequent between fields and along rivers and rivulets than they are later. More primary inoculum may have been available in antiquity than at present. The literature describes local or at least regional epidemics of black rusts with barberry bushes as their source. I have seen such epidemics in Bavaria (Federal Republic of Germany) and Yugoslavia; they must have also occurred in Italy. Tozzetti (1952) mentions several years with local or regional rust epidemics. He and Fontana (1932) agree that there was a severe black rust epidemic all over Italy in 1766; that P. graminis was the principal cause of the damage follows unequivocally from their microscopic studies.

During the early phase of the rust epidemic, uredospores are formed in great quantities. If the epidemic is severe, be it of brown or black rust, the crop acquires a reddish hue. The farmer, entering his field, will find his clothes coloured brown by uredospores; it is a threatening sight to a man who can already foresee his family going hungry next winter. Ominous associations with foxes and red dogs may come to his mind, as well as prayers to avert the evil.

During ripening the rust forms its telia. Where the crop should ripen with golden yellow colour, it turns ash-grey or - when severely infected - grey-black. The crop looks as if it had been scorched by fire. Stems and ears are densely covered by the black flecks and stripelets of P. graminis, like the charred remains after a fire. It is a sad sight, a prelude of hunger to the stricken farmer.

The great epidemic of 1766 followed a bad summer, leading to poor quality seed. Seeding was late. The winter 1765-1766 was cold, the resulting crops were thin, of poor colour, and late. Rust arriving relatively early would wreak havoc on the watery crop (Tozzetti, 1952). The relation between appearance of rust and cool nights with dew and early morning fog was well known to ancient and 18th Century observers like Tozzetti.

Astronomical information

In bygone times and the present day, farmers contemplating tomorrow's decisions looked at the sky for assurance and read the stars. The present distinction betwen astronomy and meteorology was not so evident in antiquity. Pliny's Natural History Book XVIII abounds with remarks on stars and weather in a combination typical of traditional farmers' knowledge. Sirius, the Greater Dog star, had a prominent position in the agrometeorology of the Mediterranean area, Near East and Egypt. Its morning ascent announced flooding of the Nile.

The Dog star (Kuwv or Canis) is in the constellation of the Dog which precedes the hunter Orion. Sirius is one of the clearest stars. Its Greek name is σειριος, the scorching, its Latin epitheton is flagrans, the blazing. The Dog-days began when Sirius appeared in the morning sky. Pliny placed this event at twenty-three days after solstice (24 June for him) or 17 July. The Romans placed the Dog-days, dies caniculares, between 24 July and 23 August.

To the ancient Greeks, the morning rise of Sirius announced the onset of the scorching summer heat. A chain of associations comes to mind: rust, blackened crops, summer burn, Dog-star, sacrifices.

Although the association seems attractive, there is a problem of timing. Ovid's spokesman times the premature ripening of the crops quo sidere moto, when the stars 'moves', apparently to be read as 'rises'. The premature ripening can be due to either severe rust infection or early summer drought. In this context, Pliny (line 290) mentions the caelestis sterilitas, the 'sterilizing influence of the heavens'. Apparently, Ovid did not realize that in the acts and words of his priest the two traditions, mentioned before, had merged into one, nor did he recognize the discrepancy in timing between the ascent of Sirius and the Robigalia of 25 April.

At my request Mr B. Kruseman of the Zeiss Planetarium in the Hague kindly checked some data (before the Planetarium was destroyed by fire). He stated that it must have been impossible in Rome to see Sirius at dawn before 20 July, a date at least a fortnight later than the wheat harvest!

The ancient Greeks knew that the heliacal rising of Sirius (that is Sirius and the sun rising simultaneously) took place when the sun rose in the sign of the Lion, a timing accepted by the Romans with neglect of precession and difference in northern latitudes. Today the two stars rise simultaneously in the sign Cancer. The Cancer-Lion difference is due to the precession, the astronomical phenomenon of the slow but constant change in position of the equinoxes relative to the stars. According to Mr Kruseman the heliacal rising of Sirius two thousand years ago took place about 1 September, at least one month after the wheat harvest!

Indeed, the timing does not fit. The clue is given by Pliny (Book XVIII, Part 1 LXIX, 284): 'In the eleventh year of his reign Numa established the Robigalia, which are now (ca A.D. 50) kept on 25 April, because then the rust besets the crops'. He continues (285): '(...), but the true cause is that on one of four days, according to the latitude of the observers, after the 29th day of the spring equinox (this is 19 April) until 28 April the Dog sets, a constellation of violent influence in itself (...)'. I do not know why the setting of Sirius leads to evil, but to the Romans the coincidence between an act of Sirius and the appearance of rust was apparently full of significance.

Sirius is a clear star during winter nights. When spring advances, Sirius' culmination point approaches the horizon, which is the 'setting' of Sirius. Simultaneously, the sun sets later. Sirius not only disappears slowly, but also its observation may be impeded when the sunlight becomes more intense than the mild glow of Sirius. At the Roman latitude, this happens around 25 April, when the sun is in the tenth degree of the Bull (Varro after Pliny, line 285). All these data fit together when checked by means of the Zeiss Planetarium for Rome in A.D. 1.

Indeed, there was an association between rusts and dogs, by way of a star. It was a magical association, but it made sense to the ancients. Ovid, the wordly poet, was mistaken in his timing. Pliny, the matter-of-fact scientist was more precise in his timing without going into explanations. Coincidence, year after year, suggests causality. It is most interesting that sober-minded Pliny (line 291) negates coercive causality: 'And in this matter admiration for Nature's benevolence suggests itself, as to the fact that, (...), because of the fixed courses of the stars this disaster cannot possibly happen every year, (...).

Archeological findings

Ovid records that the procession of 25 April left the city of Rome along the Via Claudia to stop at the fifth milestone for the offerings. In Ovid's time this point was well within the city limits. The tradition must have been so old that Rome's territory ended then at that fifth mile-stone. The border was the place at which to defend the town's crops (Leopold, 1968).

Few archeological findings confirm Ovid's story. In itself, however, this fact is no reason to doubt the practice. It is known that ancient Italian farmers carved their gods in wood and that altars for offerings were usually built of sods. But wood and sods are perishable commodities, leaving little for posterity.

In 1922, in a vineyard at Castiglioncelli, south of Livorno (some 200 km north of Rome) a stone cylinder was found; it measured 88 cm in height and 71 cm in diameter. It consists of reddish flint-stone quarried from nearby moutains and weighs some 800 kg. At the top, a semi-spherical basin has been carved out, 35cm deep, with two drains in which traces of lead pipes were found. The sides of the cylinder are decorated with three heads of oxen, four dogs (two sitting and two standing with curling tails), festooned with fruits, and a horned human head with snakes around the face. The human head represents the evil goddess Robigo, says Leopold (1968). In a more cautious interpretation, the horned oxes and horned head represent apotropaeic, evil averting forces. The altar dates from the first century B.C. (Galli, 1924).

Conclusion

Ancient authors and modern knowledge on crop phenology rust phenology, astronomy, and archeology can be reconcild. In ancient Rome, and probably in a wide circle around it, farmers feared the rust on wheat, in particular the black stem rust, which appeared in April. To avert the danger, they organised processions and offered (red) dogs to the rust numen Robigo. 'Please accept the dogs offered and do not take our crops'. The tradition is very old, dating from at least 700 B.C.; in Ovid's time it had already become a folkloristic event, in which two traditions had merged: one of sacrificing dogs to Robigo and another of sacrificing dogs to Sirius, the latter probably combined with the taking of omens. There is a magic association between rust, Sirius, and (red) dogs or foxes, based on coincidence of events. Ovid's 'explanation' of the association is incorrect; Pliny provides a good clue. Remnants of pre-christian tradition survive to this day in Roman Catholic and protestant liturgy. 'Pray and hope for the best' was the ancient attitude toward cereal rusts, and even in the late twentieth century, with resistance breeding and fungicides, it is the ultimum remedium.

REFERENCES

AZZI, G. - Le climat ble dans le monde. Institut International d'Agriculture, Rome, 1165 pp. 1930.
BILLIARD, R. - L'agriculture dans l'antiquite d'apres les Georgiques de Virgile. Boccard, Paris, 1928.
BROEKHUIZEN, S. (Ed.) - Agro-ecological atlas of cereal growing in Europe II - Atlas of the cereal growing areas in Europe, Pudoc, Wageningen/Elsevier, Amsterdam, 1969, 157 p.
CHESTER, K. S. - The cereal rusts; the nature and prevention of the cereal rusts as exemplified in the leaf rust of wheat. Chronica Botanica Company, Waltham, (Mass.), 1946, 269 p.
CRESCIENTIO, Piero de - De agricultura vulgare, Venice, 1511, 240 p.
ERIKSSON, J & HENNING, E. - Die Getreideroste, ihre Geschichte und Natur sowie Massregeln gegen dieselben. Mededelanden fran Landtbruks-Akadmiens Experimental-falt, Stockholm, 38, 1896, 463 p.
FONTANA, F. - Observations on the rust of grain, Phytopath. Classics, 2. 1932, 40 p.
FRAZER, F. G. (Ed.) - Ovid's Fasti. Loeb Classical Library. W. Heinemann, London, 1967, 461 p.
GALLI, E. - Castiglioncello, Scoperte di antichita varie, compresa un'ara referibile al culto di Robigus. Notizie degli Soavi, 1924, 157-178.
GOOSSEN, Th. - Hagelkruisen, voorwerpen met religieuze en profane betekenis. Ned. Volksleven, 30, (3/4), 1980, 64-75.
LEOPOLD, H. M. R. - Het moederkoren en de rode hond. In Uit de leerschool der spade. De Haan, Hilversum, 1968, 263-268.

POSTAN, M. M. (Ed.) - The Cambridge Economic History of Europe. Volume I - The agrarian life of the Middle Ages. Cambridge Univ. Press, Cambridge, 1966, 871 p.

ROGER, L. - Phytopathologie des pay chauds. Lechevalier, Paris (tome 1, 1951; tome II, 1953; tome III, 1955), 3134 p.

SIBILIA, C. - Divinity of the rust. Robigo, 3, 1957, 2-3.

SLICHER VAN BATH, B. H. - De agrarische geshiedenis van West Europa (500-1850). Spectrum (Aula), Utrecht, 1960, 416 p.

STEVENS, C. E. - Agriculture and rural life in the later Roman empire. In J. H. Clapham & E. Power (Eds). The Cambridge Economic History of Europe. I. Cambridge Univ. Press, Cambridge, 1942, 89-117.

TOZZETTI, G. Targioni - True nature, causes and sad effects of the rust, the bunt, the smut, and other maladies of wheat, and of oats in the field. Phytopathological Classics, 9, 1952, 159 p.

VERBRUGGEN, J. - Berne handmissal voor zondagen en feesten. Proost, Turnhout, 1957, 1153 p.

WHITE, K. D. - Wheat farming in Roman times. Antiquity, 37, 1963, 207-212.

TABLE 1

Data from rust interception trials near Rome (by kind permission of R. W. Stubbs). Rust was observed in 14 out of 20 years (70%). For 10 years adequate data were available. The mean date of first appearance of rust either black, brown or yellow, was calculated as $t_1 = 101$.

This Julian day corresponds to April 11.

Year	Date of observation	t_2 (1)	Maximum x observed (2)	Rust(s) observed (3)	Δt (4)	t_1 (5)
1962	07.10	191	+	R	-	-
1963	-	-	-	-	-	-
1964	?	-	1.00	GS	69	-
1965	05.05	125	+	R	-	-
1966	05.26	146	0.05	S	31	115
1967	06.06	157	-	-	-	-
1968	06.04	156	1.00	RS	69	87
1969	06.04	155	+	R	-	-
1970	06.30	181	1.00	GRS	69	112
1971	-	-	-	-	-	-
1972	06.15	167	1.00	S	69	98
1973	-	-	-	-	-	-
1974	06.04	155	0.90	GRS	42	113
1975	-	-	-	-	-	-
1976	-	-	-	-	-	-
1977	05.04	124	1.00	GRS	69	55
1978	06.02	153	1.00	S	69	84
1979	05.31	151	0.80	GRS	53	98
1980	06.18	170	0.10	RS	35	135
1981	06.15	166	0.80	GRS	33	113
						t_1=101
						s = 22

(1) Date of observation in Julian days.
(2) x = fraction of plant surface diseased, maximum of the three rusts.
(3) G = *Puccinia graminis*.
R = *Puccinia recondita*.
S = *Puccinia striiformis*.
(4) $\Delta t = \frac{}{r^{-1}} \, r^{-1}$ (logit x_2 - logit x_1) with $x_1 = 0.0001$, $r = 0.20$
(5) Calculated date (in Julian days) of first appearance of rust.

Cereal Rusts Bulletin Vol.13, Part 1, 1985

THE WHEAT RUSTS IN THE PEOPLE'S REPUBLIC OF CHINA

BY

CHANG-GHENG HU (1) AND A. P. ROELFS (2)

(1) Plant Pathologist, Xuzhou Agriculture Research Institute, Jiangsu, People's Republic of China, currently visiting Scientist - (2) Research Plant Pathologist, Cereal Rust Laboratory, University of Minnesota, St. Paul, Minnesota 55108.

SUMMARY

Physiologic races and epidemiology of stem rust (*Puccinia graminis* Pers. f. sp. *tritici*), leaf rust (*P. recondita* Rob. ex Desm. f. sp. *tritici*) and stripe rust (*P. striiformis* Westend.) of wheat have been studied for 40 years in China. Most of the results have been presented at conferences and/or published in Chinese. Fifteen physiologic races of stem rust were identified, i.e. 17, 19, 21, 12c1, 12c2, 12c3, 34, 34c1, 34c2, 34c3, 40, 194, 207, 72-4x, and 74-1x. The race 21 cluster was dominant, while the 34 cluster was also common. Eleven leaf rust races were identified, i.e. CL-1, CL-2, CL-3, PP-2, PP-3, PP-5, PP-6, PP-7, PP-11, PP-13, and Shantong-A. Twenty-five races of stripe rust were found and designated as China Stipe (CS) 1 to 25. Races 17, 18, 19, and 21 were the most prevalent in the 1970's and races 22, 23, 24, and 25 were dominant after 1980.

INTRODUCTION

Wheat, an important food in China, is grown on 27 to 29 million ha annually. The main production areas are northern and north eastern China. The average yield of wheat has been rather low, about 0.5 tonne/ha, while a highly productive farm may produce 5 tonne/ha. The former low yields resulted from improper irrigation, insufficient fertiliser, and the damage done by rust diseases (3).

Stripe, leaf, and stem rust occur annually on wheat in China. Historically the most serious damage was done by stem rust. However, there has not been a serious national epidemic since 1964.

Stem rust mainly occurs on spring wheat of north eastern China, Nei Mongol, and north western China, and in the fall-sown wheat areas of the Yangtze River Basin and south eastern maritime provinces. The uredial stage of stem rust overwinters in south eastern maritime provinces. In Putian and Jinjiang of Fujin Province (Fig. 1) stem rust uredia appear in January. The uredospores are airborne northward to east and north China, then to north east China. The pathogen oversummers in north and north west China, where it occurs on the volunteer wheat and the seedlings of early planted winter wheat in the fall, and finally reappears in south and south east China where it overwinters.

Stripe rust was important in north and north west China, in 1958 and 1964, when severe losses occurred in Gansu, Shaanxi, western Sichuan, north China and Nei Mongol. Stripe rust oversummers on wheat at altitudes of 1500-2000 metres in western Sichuan and eastern Gansu where summer temperatures do not exceed 22^{o} C. Stripe rust can survive the entire year by moving up and down the mountains with the varying wheat growing seasons. New races are often found in these areas. The inoculum is airborne southeastward in the fall to Sichuan and Yunnan where it overwinters on wheat growing areas along river banks. In the spring, stripe rust spreads northward and eastward to Shanxi, Shaanxi, Henan, and Jiangsu Provinces. In the summer inoculum may be carried to Gansu by winds from the east.

Leaf rust occurs throughout China on winter and spring wheats. Because most of the commercial cultivars are susceptible, leaf rust often became severe and resulted in serious losses in the 1970's. Currently it is a major threat to wheat production in China.

In China, agricultural organisations, including the Ministry of Agriculture in Beijing, the provincial bureaux, the county departments, rural communes, agricultural colleges, and professional schools, all have a department of or institution of plant protection. Plant protection includes plant disease and pest control, dissemination of information and some research projects.

Few research studies on wheat rust in China are published in a language readable by the international community of plant pathologists. This paper summarizes the work on wheat rust diseases in China. Transliterations of Chinese names are by the Hanyu Pinyin systemi; for the formerly used names are also given in Fig. 1.

LITERATURE REVIEW

STEM RUST (*Puccinia graminis* Pers. f. sp. *tritici*)

Races were identified at the Shenyang Agricultural College under the leadership of Y.S. Wu and at the Xuzhou Agricultural Research Institute of Jiangsu Province. Between 1956 and 1975, 8,490 samples were identified. The international differential series (18) was used. Between 1956 and 1961, investigators found that some new cultivars, were susceptible one year, and resistant in another to cultures of the same race. Between 1961 and 1964, a supplementary differential set of M52, EC6, and Minn. 2761 were chosen for use in China. These lines distinguished between members of race 21 and 34 clusters (Table 1).

Rust races were identified in the greenhouses of the institutions using standard procedures (15). Races 17, 19, 21, 21c1, 21c2, 21c3, 34, 34c1, 34c2, 34c3, 40, 194, 207, 72-4x and 74-1x of stem rust were identified. In 1978, at a national plant pathology symposium, Y.S. Wu summarized the occurrence of races of stem rust in China. The frequency of stem rust is shown in Table 2. Before 1978, the race 21 cluster (races 21, 21c1, 21c2, 21c3) made up 88.6% of the sampled population. Before 1963 no distinction between members of the race 21 cluster were made. In 1963, using three supplementary differential cultivars, it was apparent that races 21c2 and 21c3 were the dominant phenotypes. The frequency of biotype 21cl has remained low and it is possible that it is avirulent on most of the wheat cultivars of China.

Race 34 cluster was also relatively frequent (8.6% of all isolates) and widely distributed. Since 1962, 34 and 34cl have been most widespread and frequent of the phenotypes in this cluster. The frequency of 34c2 is low, but it has resulted in serious yield losses (2). Race 34c3 was recently found (8) and has been reported in at least ten provinces (4).

Race 40 is virulent on most wheat cultivars. It has been found in 15 provinces, however, its frequency is rather low (1%), and it has not been found since 1973. The reasons for scarcity of this race are unknown.

LEAF RUST (P. recondita Rob.ex Desm. f. sp. tritici)

A pioneer study on leaf rust was done in Yunnan Province by Wang (17). H. L. Wang, with the analysis of 417 samples from 1949 to 1951 found that the international differentials were not useful in China, because of variations in temperature and short day length of Yunnan (19). In 1963-64, studies were initiated by the Academy of Agricultural Sciences, Beijing, but were interrupted by the Culture Revolution, until 1973, when work was resumed by K. M. Wang and his staff at the Academy of Agricultural Sciences, in cooperation with H. R. Wang at Hebei Agricultural University at Baoding. A preliminary survey on the virulence of leaf rust on various Chinese wheat cultivars was made along with extensive collections and intensive studies of wheat leaf rust (1,19).

A new set of leaf rust differentials was selected from 100 cultivars with 26 single uredial isolates from 11 provinces. The infection types produced by each race are shown in Table 3. A total of 1,237 leaf rust samples was analysed from 14 to 18 provinces per year from 1974 through 1978. In August 1977, a uniform system of nomenclature was adopted for the three major races; CL-1, CL-2, and CL-3 (C = China, L = leaf rust) (18,19). Eleven physiological races of leaf rust were recognised. Their prevalences are shown in Table 4.

Race CL-1 was widely distributed in China. It comprised 49.6% and 45.5% of the isolates identified in 1974 and 1978, respectively. Races CL-2 (11.1% in 1974 and 6.1% in 1978) and CL-3 (12.9% in 1974 and 19.4% in 1978) were less common (19). Race CL-1 is virulent on the cultivars Nongda 155 and 156, Funo, Ganmai 8, Taishan 1 and avirulent on Baiyoubao, Taishan 4, Lovrin 10 and Lovrin 13, and moderately avirulent on Fengchan 3. Race Cl-2 is virulent on Dabaike which was immune to CL-1. Races CL-1 and CL-3 are virulent on Zhangzhou 3, while Cl-2 is avirulent. Shangong-A found in 1978 is important because of virulence on Taishan 1, which is the most important cultivar in China.

Ten selected races were tested on 10 single gene lines and 5 cultivars. Based on the response to these races Lrl, 2a, 2c, 3, 3bg, 3Ka, 14a, 16, 17, 18, and the cultivars Agatha (Lr 19), Trensio (Lr 30), Wanken, Waldron (Lr2a+), and El Gaucho (Lr 11?), with the exception of Lr 18 all lines differentiated between some cultures in China (19). The reaction of the lines and cultivars are shown in Table 5.

Virulence differences exist between geographical areas. In 1975, the cultivar Baiyoubao was resistant in Taian and Changsa, but heavily infected in Yantai, Dezhou, and Zunyi. Efforts are underway to investigate the pathogen races with ecological and genetic emphasis. Currently resistance to races CL-1, CL-2, Cl-3, PP-3, PP-11 and Shandong-A should be the main goals of the breeding for leaf rust resistance.

STRIPE RUST (P. striiformis Westend.)

In the 1940's race identification of stripe rust was done by C. T. Fang with the differential hosts of Gassner and Straib (14). Nine races were found in the collections of southwest China and 5 races in east China (5,6). In the early 1950's, S. I. Lu and K. N. Wang identified collections chiefly from north China using the Gassner and Straib differentials or a set of 14 improved Chinese cultivars (14).

Thereafter, most of the race identification of stripe rust was done by K. N. Wang at Academy of Agricultural Sciences, Beijing and at the Shaanxi Academy of Agricultural Sciences, Wugong. The host responses of the selected differential cultivars produced by some races of stripe rust in China are shown in Table 6. Between 1950 and 1960, using selected hosts from the Gassner and Straib and the Chinese differential sets, 16 physiologic races were identified. They were China Stripe (CS) 1-16. A new physiologic race with additional virulence was found as each new commercial cultivar became susceptible. In the 1970's, China Stripe rust races 22, 23, 24 and 25 were found and they are the dominant races currently. The frequency of the important races of stripe rust is shown in Table 7.

Three groups of cultivars differing in stripe rust resistance have been used in China (11,12). Originally, Bima 1 was resistant to stripe rust and it was planted extensively by 1952. By 1957, its resistance was ineffective, along with that of Northwest 54, Northwest Fengshou, and Nongda 183. The resistant cultivars Yupi, Gansu 96, Shannong 9, Nanda 2419 were planted extensively by 1957. They in turn became susceptible to stripe rust before 1964, along with Xinong 6028, Zhungnong 28, Northwest 612, Northwest 134, Shannong 1, and Nongda 311. The cultivars Abao, Fengchan 3, Jubilyna 11, Beijing 8 were planted extensively after 1964 and were susceptible to stripe rust by 1975 along with the cultivars Ganmai 8; Tianxuan 15, 16, and 17; Aifeng 3 and 4; Xinong 68; Weidong 8; Mingxian 4; nad Zhengying 1 (12).

An increase in virulence of the pathogen was the primary cause of the loss of effective resistance of wheat cultivars to stripe rust. The new race increased as the area planted to the new wheat cultivars increased, and these races often became dominant in the population. Consequently, the new cultivars were severely rusted and had little agricultural value.

In June 1976, in Tianshiu, Gansu, investigations indicated that Taishan 1, Shanqianmai, Aquilei and particularly Lovrin 10 and Lovrin 13 were no longer resistant to stripe rust (12, 13). In some fields of Lovrin 10 a 70% incidence with a 10 to 65% severity of stripe rust was observed of infection types 1 through 3. Lovrin 10 and 13 are the principal sources of resistance used in north China. If stripe rust continues to evolve, sources of resistance will be seriously limited.

Races CS 17 and 18 that dominated in the mid-70's and race 20 that was important locally were replaced by races 22, 23, 24, and 25 in 1980's. The virulence of these races are as follows:

CS 22 is virulent to adult plants of Kang-yin 655 and to the commercial cultivars, Apo; Fengchen 3; Chengyin 1; Hsiaoyen 4 and 5;Tianxuan 15, 17 and 34; Tian 763; Jubilyna 11; Zhungling 5 and 11; Beijing 15 and 16; Nongda 139, 168, 181 and 198; and Taishan 1 and 4.

CS 23 (formerly 19-1) is virulent to Kaochaiso which was widely used as a resistant parent. It is also virulent to Taishan 1, Fengchen 3, Apo, Taishan 4 and moderately virulent to Chengzhou 761, Jinnan 13, and Hsiangyeng 4.

CS 24 (formerly 19-3) is avirulent to only the middle and lower leaves of Taishan 1. Race 24 is the most virulent to Chenzhou 761, Hsiaoyan 4, Tianxuan 33 and 34, and less virulent to Taishan 4, Jinnan 13, Nongda 139 and Aquilei. Race 24 is mainly found in eastern Gansu, Shannsi and north China.

CS 25 (formerly 19-4) is most virulent to the widely grown cultivar Taishan 1 and the important cultivars Fengchen 3, Apo, Nongda 139, Dongfanghung 3, Hsiangyang 4, Jian 6, Zhohgling 5 and 11, Shioyefdn 4, Zhengchow 761, Jinnan 13, Gao 8 and Aquilei.

RESULTS

Three new races (72-4X, 74-1X and 34c3) of wheat stem rust on the differential cultivars were identified in China at the Xuzhou Agricultural Research Institute, by the senior author (8, 9, 10).

Race 72-4X; Between 1956 and 1975, 12 physiologic races were known in China. In 1972, a unique resistant reaction on Kota producing an infection type 1 was observed. The larger uredia had distinct necrotic areas. Spores from the type 1 infection reinoculated to Kota again produced type 1 and 4 infection types. Infections produced on the international differential set showed that the reaction of this race was different (15). The race was designated 72-4X to indicate the year of discovery, and a X infection type on the 4th differential cultivar. The host response of the Chinese differentials to 72-4X is shown in Table 1. Between 1972 and 1975, 44 samples of 72-4X were found at 13 sites in 5 provinces (Table 8).

Race 72-4X was studied between 1972 and 1975 with 175 trials. The results were presented at an April 1976 meeting conducted by Y. S. Wu, for the investigators of wheat stem rust in Shenyang Agricultural College. Confirmatory studies were conducted in Keshan Agrucultural Institute of Heilongjiang Province. Inoculation with race 72-4X was done at Keshan on April 29, 1976. On May 12, Y. S. Wu, Y. Fan and the senior author confirmed that 72-4X was a new race of stem rust.

During the winter of 1976 under the influence of the "Gang-of-four" the greenhouse of Shenyang Agricultural College was damaged beyond use. The research team moved to Xuzhou for cooperative experiments. Samples collected throughout China showed that race 72-4X occurred also in Sichuan, Zhejiang, Hunan and Liaoning province, making up 3.9% of the isolates.

In November 1978, a nationwide symposium on plant pathology was held in Guilin, Guangxi at which Y. S. Wu and his group reported on the investigations with race 72-4X which they designated Kota 1 type.

Race 74-1X: A type 2 infection was observed on Little Club seedlings with several isolates by the senior author. In November of 1974, these cultures were studied at Shenyang Agricultural College. When spores were taken from type 2 uredia and inoculated to Little Club, both 2 and 4 type infections were observed. These cultures were designated 74-1X, (Little Club being the 1st differential host). Occasionally this culture produced an infection type 2 on Marquis but this response was inconsistent.

In 1974 and 1975, 74-1X was collected in 4 sites in Jiangsu Province; from the cultivars Xuzhou 15, Fengchan 3, Hubei 398, and Xinyang 225 in Xuzhou; Funo in Shuyang; from Yangmai in Gaoyu; and from an unknown cultivar in Xhzhou.

Race 34c3: The Shenyang Agricultural College team had found three biotypes in the race 34 cluster, ie. 34, 34c1 and 34c2. These biotypes are virulent on wheat line EC 6. The senior author found another strain in this cluster that produced both infection types 0-1 and 4 on EC 6. In 1973, it was suggested that this phenomenon may have been caused by an unknown rust biotype or by a host seed mixture (7). After several years of studies evidence indicated that a new pathogen phenotype was the cause of the mixed reaction. The race was designated 34c3 in 1975.

Between 1972 and 1975, 33 samples of race 34c3 were found. They were from 10 sites in Heilongjiang, Nei Mongol, Shandong, Jiangus and Henan Provinces. In 1976, scientists at the Shenyang Agricultural College reported that race 34c3 occurred in Yunnan, Guizhou, Sichuan, Jiangsu, Shandong, Shanxi, Liaoning, Jilin and Nei Mongol (4). Race 34c3 comprised 23.7% of their isolates, less only than 21c3, the dominant race. They concluded that 34c3 may have been overlooked in previous years.

The discovery of race 34c3 has a far reaching significance in the control of wheat stem rust and in the breeding for resistance in China. Orofen, an important parental cultivar, is susceptible to 34c3. The potential threat to wheat production in China attracted the attention of wheat breeders and governmental leaders. At the Science Conference of Jiangsh Province in 1978, an award of special honour was given for detection of race 34c3 prior to it causing serious damage. Likewise, in 1978, the Liaoning Science Conference granted a joint citation and monetary award to Shenyang Agricultural College and Xuzhou Agricultural Research Institute.

CONCLUSION

The Chinese scientists have been isolated for about 50 years, first due to early involvement in World War II, and then because of certain national policies. The pioneers who undertook investigations of the physiologic races of the wheat rusts are still working. They were trained abroad and returned to China in the late 1930's and early 1940's. They are the professors in governmental institutions, or in plant protection departments and various agricultural colleges. They have trained their co-workers and many have worked under unfavourable conditions and with inadequate facilities. However, with an undefeatable spirit and high motivation they were useful to the people and country. Many difficulties were overcome and some satisfaction and success was attained in understanding the disease and its control. Thereby, they have increased wheat production in China.

A unique characteristic of the work is the collaboration of many scientists from different institutions. Cooperation includes annual and biennial meetings in which information is shared, progress and problems discussed, and future studies planned. Each Chinese institution belongs to the country and the people. The successes and awards are given to the institutions. Recently authorship of publications has been credited to the organisation, thus, the large number of "anonymous" articles in the bibliography.

The plant pathologist in China has always had the cooperation and assistance from the staff members of provincial and county plant protection departments and of the people of the villages who supply pathogen samples and information on host response. Hostels are provided free or for a nominal charge for a member of a "brother institution".

Acknowledgement: Deep appreciation is expressed to Professor Y. S. Wu for a quarter century of teaching and encouragement, to the colleagues at the Xuzhou Agricultural Research Institute who shared the difficulties and anxieties as well as the joy of discovery. The authors express their thanks to Dr. Shjiu Ying Hu for her assistance and for the design of the figure.

REFERENCES

ANON. 1973. A preliminary report on the virulence of brown leaf rust and stripe rust on wheat cultivars. Scientific Plant Protection 3: 79-101.

ANON. 1976. The 1975 summary of the identification and analysis of the physiological races of wheat stem rust in twenty provinces and special districts of China. The National committee on cooperative studies and control of wheat stem rust. Shenyang Agric. College. 22pp.

ANON. 1978. The principal achievments and guidelines for the studies on the conditions, regularities, and rules in the occurrence of wheat rust diseases. Committee on nationwide collaboration in the prevention and control of wheat diseases. 12pp.

ANON. 1978. A summary of the identification and analysis of the studies of Puccinia graminis f. sp. tritici during 1956-1965 and 1973-1976. Dept. Plant Protection, Shenyang Agric. College. 38pp.

FANG, C. T. 1944. Physiologic specialization of Puccinia glumarum Eriks. and Henn. in China. Pathology. 1:155-156.

FANG, C. T. and GHEN, S. Y. 1955. Seedling and resistance tests of wheat cultivars to stripe rust and variation of Puccinia glumarum. Pathol. 1:155-156.

HU, C. C. 1976. An annua report on the programme and progress in the identification of physiological races of Puccinia graminis f. sp. tritici. Xuzhou Agric. Res. Instit. Jiangsu Province. 16pp.

HU, C. C. 1978. New physiological races of Puccinia graminis f. sp. tritici, discovered recently. Xuzhou Agric. Res. Instit. 15pp.

HU, C. C. 1980. Stem Rust in People's Republic of China. Mycol. Soc. Am. Newsletter 31:24.

HU, C. C. 1980. My participation in combating wheat stem rust in China. Masters Thesis Univ. of New Hampshire 22pp.

LI, Z. Q. 1978. On the reduction and loss of the resistance to wheat rust. The Northwest Agric. College. 22pp.

LI, Z. Q. 1982. The variation of wheat variety resistance to stripe rust in China --- Causes and solution. Northwest Agric. College 6pp.

LI, Z. Q., SHANG, H. S., YIN, X. L., QIANG, Z. F., ZHAO, Y. Q., Lu H. P., Hong, X. W., Song, W. Z., Lin, S. J. 1982. Studies on the breakdown of resistance of wheat cultivars to Lovrin 10 and Lovrin 13 to stripe rust (Puccinia striiformis West.) Northwestern College Agric. Press. 11pp.

LU, S. I., FAN, K. F., SHIA, S. M., WU, M. T., KONG, S. L., YANG, T. M., WANG, K. N., and LEE, S. P. 1956. Studies on stripe rust of wheat. I. Physiologic specialisation of Puccinia glumarum (Schmidt) Erikss. and Henn. Acta Phytopathol. Sin. 2:253-166.

STAKEMAN, E. C., STEWART, D. M., and LOEGERING, W. Q. 1962. Identification of physiologic races of Puccinia graminis f. sp. tritici. U.S. Dept. Agric. ARS E617.

TSENG, S. M. 1978. On the horizontal resistance of plants. North China Agric. Univ. Beijing. 13pp.

WANG, H. R. 1947. Notes on physiological specialisation in leaf rust of wheat in China. Phytopathology 37: 680-681.

WANG, H. R. 1978. A discussion on the physiologic races of Puccinia recondita Rob. ex. Desm. Hebei Agric. College, Dept. Plant Protection 10 pp.

WANG, K. N., LIU, M. Y, XIE, S. S., and LI, F. C. 1982. On the physiologic specialisation of leaf rust of wheat in China. Acta Phytopathol. Sinica 12:1-8.

TABLE 1 - Infection types produced by physiologic races of *Puccinia graminis* f. sp. *tritici* on the Chinese supplemental differential cultivars.

Supplemental host	Infection types for races														
	17	19	21	21 c1	21 c2	21 c3	34	34 c1	34 c2	34 c3	40	72-4x	74-1x	194	207
M 52	0	4	0	4	0	4	0	4	4	4	4	0	0	0	0
EC 6	0	4	0	0	4	4	4	4	4	0	4	0	0	4	4
Minn 2761	0	0	0	0	0	0	0	0	4	0	4	0	0	0	0

TABLE 2 - Percentage of each physiologic race of wheat stem in China during 1956-1965 and 1973-1976

Year	No of samples	Percentage of each race													
		17	19	21	21 C1	21 C2	21 C3	34	34 C1	34 C2	34 C3	40	194	207	72-4X
1956	315	0	0	84	-	-	-	12	-	-	-	4	0	0	-
1957	380	26	0	71	-	-	-	*	-	-	-	0	0	0	-
1958	717	0	0	94	-		-	3	-	-	-	3	0	0	-
1959	75	0	0	89	-	-	-	11	-	-	-	0	0	0	-
1960	334	0	0	72	-	-	-	25	-	-	-	3	0	0	-
1961	334	2	0	86	-	-	-	5	1	-	-	2	0	0	-
1962	510	*	0	82	6	8	2	2	*	0	-	0	0	0	-
1963	1115	0	*	29	13	28	21	4	3	0	-	2	0	0	-
1964	2006	*	*	30	4	30	18	10	6	*	-	1	*	0	-
1965	1266	*	0	14	*	74	9	2	*	*	-	*	0	*	-
1973	399	0	0	3	*	16	76	2	2	*	-	0	0	0	-
1974	638	*	0	2	1	15	75	1	3	*	-	0	0	0	-
1975	406	0	0	11	4	17	53	6	9	1	-	0	0	0	-
1976	135	2	0	8	7	7	26	8	14	2	24	0	0	0	4

- = not evaluated, * = less than .06 percent.

TABLE 3 - Host response of the Chinese differential set for wheat leaf rust.

	Host response for race										
	CL	CL	CL	PP	PP	PP	PP	PP	PP	PP	Shantong
Host	-1	-2	-3	-2	-3	-5	-6	-7	-11	-13	Type A
Baiyoubao	R	S	S	S	S	S	S	S	S	R	S
Dongfanhung 3	S	S	S	S	S	S	S	S	R	R	R
Fenchan 3	S	S	S	S	S	I	S	R	R	R	R
Xinong 6068	R	R	S	R	R	R	R	R	R	R	R
Lourin 10	R	R	R	S	R	S	R	R	R	R	R
Taishan 4	R	I	S	S	S	I	S	S	I	R	R
Taishan 1	S	S	S	S	S	R	S	S	R	R	R
IRN 66-331	R	R	S	S	S	R	S	S	R	R	R
Redman	R	R	S	S	S	R	S	S	R	R	R

R = resistance, S = susceptible, I = intermediate.

TABLE 4 - Percentage of the isolates of each physiologic race of wheat leaf rust identified from China during 1974-1978.

No. Year	No. of samples	Percentage of each race										
		CL -1	CL -2	CL -3	PP -2	PP -3	PP -5	PP -6	PP -7	PP -11	PP -13	Shandong Type A
1974	109	50	11	13	2	6	1	1	1	10	2	-
1975	207	49	12	12	1	10	1	-	-	15	*	-
1976	235	44	14	25	*	4	2	-	-	8	1	-
1977	380	45	13	15	*	3	4	2	4	11	1	-
1978	315	46	6	19	1	1	*	2	1	9	*	13

- = not evaluated, * less than 0.6 percent.

TABLE 5 - Host response of selected lines and cultivars to Chinese races of wheat leaf rust.

	Host response to race									
	CL	CL	PP	PP	PP	PP	PP	PP	PP	PP
Host	-1	-2	-2	-3	-5	-6	-7	-8	-11	-13
Lr 1	I	S	S	S	S	S	S	R	S	S
Lr2a	I	R	R	R	S	R	-	R	I	S
Lr2c	S	S	S	S	R	S	R	S	I	S
Lr 3	S	S	S	S	R	I	R	R	R	R
Lr 3ba	S	S	S	S	R	S	S	I	R	R
Lr 3ka	I	R	S	S	R	S	S	S	R	R
Lr 14a	S	S	S	S	S	R	R	S	I	S
Lr 16	S	S	S	S	R	S	S	S	I	-
Lr 18	S	S	S	-	S	S	S	S	S	S
Agatha	R	R	R	R	R	R	R	I	R	R
Terenzio	I	I	I	S	R	I	R	S	R	R
Wanken	R	R	R	R	-	R	R	R	R	R
Waldron	R	R	-	-	-	R	R	R	R	R
El Gaucho	I	S	I	S	R	S	R	S	R	R

I = Intermediate, S = Susceptible, R = Resistant, and - = not evaluated.

TABLE 6 - The host responses of the differential cultivars produced by selected races of stripe rust in China.

	Host response to races CS												
Host	1	8	10	13	17	18	19	20	21	22	23	24	25
Eureka	R	R	R	S	I	R	R	R	I	S	S	I	I
Fulhard	R	S	S	S	S	R	S	S	S	S	S	S	S
Bima 1	S	R	S	I	S	S	S	S	S	S	S	S	S
Lutescens 128	S	R	R	R	R	S	S	R	S	S	S	S	S
Northwest Fengshou	S	R	S	I	S	S	S	S	S	S	S	S	S
Northwest 54	S	R	S	R	S	S	S	S	S	S	S	S	S
Yupi (Quality)	R	S	S	S	S	S	S	S	S	S	S	S	S
Nanda 2419 (Mentana)	I	R	I	S	I	I	S	S	I	I	S	S	S
Gansu 96 (CI 12203)	R	S	S	S	S	S	S	R	S	S	S	S	S
Virgilio	R	R	R	R	R	R	R	R	R	R	R	R	S
Abbondanza	R	R	R	S	I	S	S	R	S	S	S	S	S
Beijing 8	I	R	I	R	S	S	S	S	S	S	S	S	S
Early Premium	R	R	R	S	S	I	S	R	S	S	S	S	S
Funo	R	R	R	I	R	I	S	S	I	I	S	S	I
Danish 1	R	R	R	R	R	S	S	R	I	I	S	R	I
Jubilyna II	R	R	R	R	R	R	R	R	S	S	R	R	R
Fengchan 3	R	R	R	R	I	I	S	S	S	S	S	S	S
Strubes Dickkopf	R	R	R	S	I	R	I	R	I	-	-	-	-
Louvrin 13	-	-	-	-	R	R	R	R	R	R	R	R	R
Kangjin 655	-	-	-	-	R	R	R	R	R	S	R	R	R
Taishan 1	-	-	-	-	S	S	I	R	I	I	I	I	I

R = resistant, I = intermediate, and S = susceptible.

TABLE 7 - Frequency of important physiologic races of wheat stripe rust in China, annually.

Year	Percentage of race CS-												
	1	8	10	13	17	18	19	20	21	22	23	24	25
1961	66	29	2										
1964	30	4	50	7									
1972	2	*	3	-	43	32	6						
1974	*	2	4	*	16	50	10	12					
1975	*	*	4	-	39	19	22	1	*				
1976	-	-	-	-	35	10	48	*	3				
1977	-	-	-	-	-	-	81	-	-				
1979	-	-	-	-	-	-	-	-	-	2	37	13	13
1980	-	-	-	-	-	-	-	-	-	2	28	18	18
1982	-	-	-	-	1	1	9	-	3	7	16	2	44
1983	-	-	-	-	*	*	11	-	3	16	13	1	33

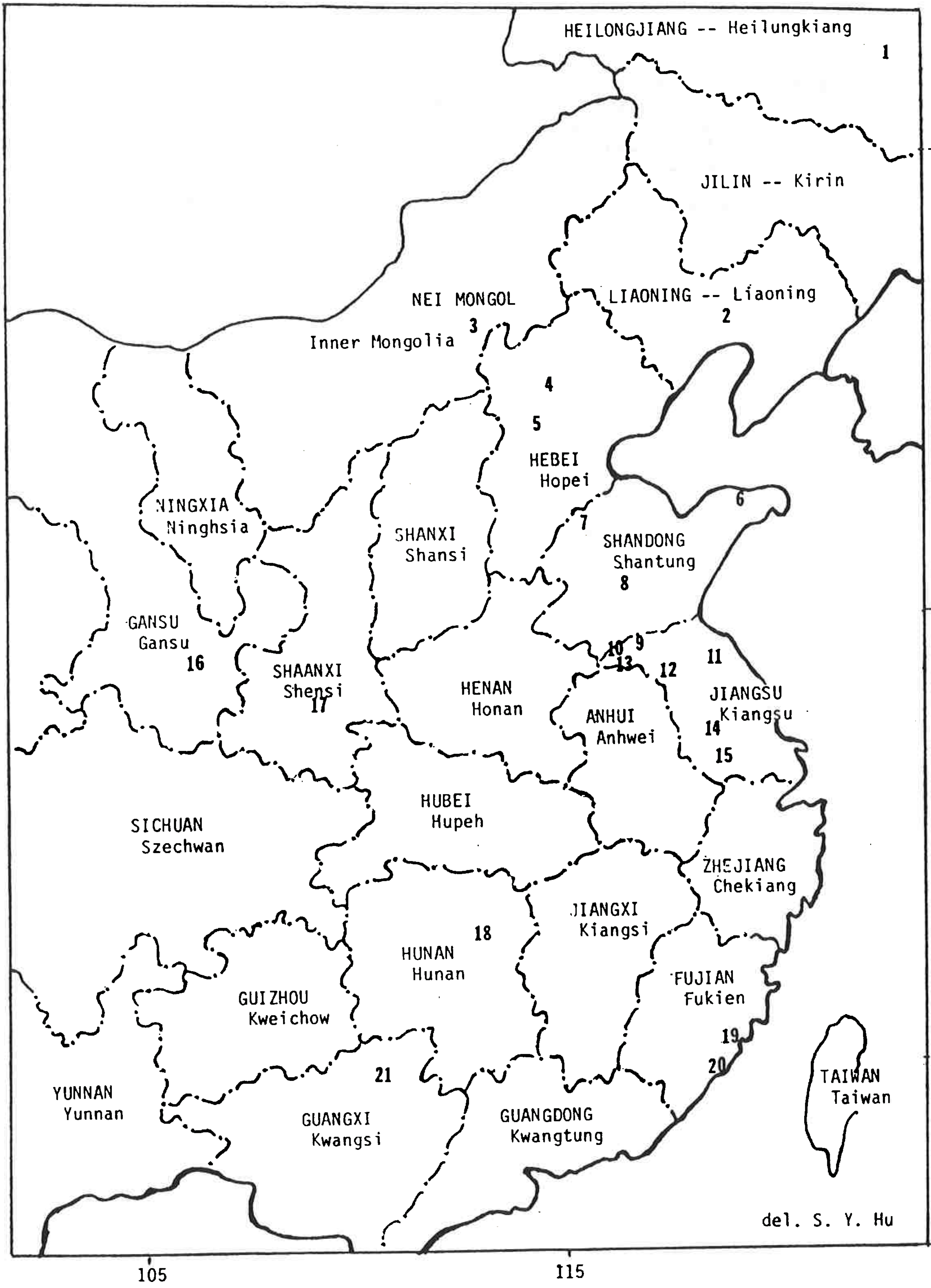
- = not found, * = less than .06%.

TABLE 8 - Source and host from which Chinese race 72-4X was collected.

Province	City	Cultivar
Heilongjiang	Hejiang	Liangjiang
Nei Mongol	Hohhot	White Orofen, Gaofeng, Chuntaifu 28, r C 430
Hebei	Baoding	Youzi
Jiangsu	Xuzhou	Little Club, Xuzhou 14, Xuzhou 15, Taishan 4, Bima 1
	Peixian	2411
	Pixian	Aifeng 1
	Xuqian	Xuzhou 14
	Ganyu	Gameili
	Shuyang	Funo
	Gaoyu	Yangmai 1
	Nanjing	Zhongnong 28
	Suzhou	Unknown
Jianqxi	Nanchang	Hubei 6

Figure 1: Map of Chinese cities cited. Numbers were assigned to localities from north to south and east to west. Baoding 5, Beijing 4, Changhsa 18, Dezhou 7, Gaoyu 14, Hejiang 1, Hohot 3, Jinjiang 20, Keshan 0, Nanjing 15, Peixian 10, Pixian 9, Putian 19, Shenyang 2, Shuyang 11, Taian 8, Tianshui 16, Wugong 17, Xuqian 12, Xuzhou 13, Yantai 6, Zunyi 21.

Figure 1


HEILONGJIANG -- Heilungkiang
1
-45
JILIN -- Kirin
NEI MONGOL
3
Inner Mongolia
LIAONING -- Liaoning
2
4
5
HEBEI
Hopei
6
7
NINGXIA
Ninghsia
SHANXI
Shansi
SHANDONG
Shantung
8
-35
GANSU
Gansu
16
10
9
13
12
11
SHAANXI
Shensi
17
HENAN
Honan
ANHUI
Anhwei
JIANGSU
Kiangsu
14
15
SICHUAN
Szechwan
HUBEI
Hupeh
ZHEJIANG
Chekiang
JIANGXI
Kiangsi
18
HUNAN
Hunan
FUJIAN
Fukien
GUIZHOU
Kweichow
19
-25
20
21
TAIWAN
Taiwan
YUNNAN
Yunnan
GUANGXI
Kwangsi
GUANGDONG
Kwangtung
del. S. Y. Hu
105
115

Cereal Rusts Bulletin Vol.13, Part 1, 1985

THE SPECTRUM OF RESISTANCE IN RYE TO PUCCINIA GRAMINIS AND P. RECONDITA

BY

G. L. C. MUSA

Mt. Makulu Research Station, Private Bag 7, Chilanga, Zambia

SUMMARY

The spectrum of resistance present in seven inbred lines of rye (Secale cereale) and sixteen F4 lines were tested for seedling reaction to wheat leaf rust races 5, 9, 15, 30, 76, 126a and rye leaf rust isolate RLR 213/78. The seven inbred lines were also tested for seedling reaction to wheat stem rust races C17, C53 and C61 and rye stem rust isolates RSR 447/78, RSR 59/79, and 101/80. Field reaction was tested in a rust nursery.

The reactions to rye stem rust were variable suggesting a high degree of physiologic specialisation in rye stem rust. All the inbred lines expressed good field resistance to both leaf rust and stem rust of wheat. These results indicated that the inbred lines tested possess both seedling and field resistance. The importance of rye as a source of genes for disease resistance is discussed.

Index words: Secale cereale, stem rust, leaf rust, disease resistance.

INTRODUCTION

Rye, Secale cereale L. (2n = 14) is a potential source of genes for disease resistance in wheat (Triticum aestivum L.). Resistance offers an efficient disease control method for cereal crops. However, the rust fungus (Puccinia sp.) is one of the most specialised fungi attacking cereals. Stem rust (P. graminis Pers.) and leaf rust (P. recondita Rob ex Desm.) are complex and divided into several formae speciales.

Several cultivars of rye resistant to leaf rust have been reported. Mains and Leighty (1923) and Mains (1926) discovered some genotypes of rye resistant to rye leaf rust (P. recondita f. sp. secalis). Mains (1926) obtained plants of Abruzzes rye which were highly resistant to leaf rust and stem rust. Several cultivars of rye resistant to leaf rust and stem rust have been developed by Morey (1956, 1973). The importance of rye as a source of genes for rust resistance was demonstrated through intergeneric transfers (Acosta, 1963; Driscoll and Jensen, 1964; Rao, 1977). Zeller (1973) reported that several European cultivars derive their resistance to P. graminis, P. recondita and P. striiformis from rye chromosome 1R, which was substituted for wheat chromosome 1B or was translocated with chromosome 1B.

The need to identify sources of disease resistance for use in broadening the genetic variation in rye, wheat and triticale breeding programmes is very important. The purpose of the present study was to determine the reaction of rye to cultures of *P. graminis* and *P. recondita*.

MATERIALS AND METHODS

The seedling reaction of seven inbred lines of rye to stem rust and leaf rust were evaluated in greenhouses during the winter and spring months of 1980 at the Canadian Department of Agriculture, Research Station, Winnipeg, Manitoba. The inbred ryes used in this study have been described elsewhere (Musa et *al*., 1984).

Inoculum

Three races of wheat stem rust C17, C53, C61 and three isolates of rye stem rust RSR 447/78, RSSR 59/79 and RSR 101/8 were used in studying the reaction of rye to stem rust. In testing the reaction to leaf rust, six wheat leaf rust races 5, 9, 15, 30, 76, 126a and one isolate of rye leaf rust RLR 213/78 were used. The rust cultures used had been stored in a vacuum and increased on susceptible cultivars. Both wheat stem rust and rye stem rust were increased on Litle Club wheat while Rosen rye was used for increasing rye leaf rust and rye stem rust.

Green House Experiment

The rye seedlings were grown in 3 inch pots at five plants per pot. At the 1 to 1.5 leaf stage the plants were inoculated by shaking urediospores from rusted plants. Inoculated plants were incubated at approximately 100% relative humidity for 18 to 24 hours and classified for rust reaction 12 to 14 days later using the system described by Stakman et *al*., (1962).

Field Experiment

In order to study the field reaction, the seven inbred ryes were grown in a Rust Nursery at the Glenlea Research Station during the summer of 1980. The nursery was artificially inoculated with a mixture of wheat leaf rust and stem rust. Adult plants were recorded as per cent of infection according to the modified Cobb Scale.

RESULTS

Seedling Reaction

Stem Rust

The seedling reactions produced on each inbred line of rye are shown in Table 1. All the inbreds were found to be highly resistant to the three wheat stem rust races. Reactions to the rye stem rust isolates were variable. Inbred line UM 8071 was susceptible to all rye stem rust isolates while UM 8336 and UM 8340 were highly resistant giving fleck (;) reactions to both wheat and rye stem rust. The other inbred lines UM 8003, UM 8116, UM 8295 and UM 8301 were resistant to all the wheat stem rust races.

Leaf Rust

The seedling reactions to both wheat and rye leaf rust are presented in Table 2. Inbred lines UM 8295, UM 8336 and UM 8349 gave highly resistant reactions to the test races. Seven F4 lines selected from crosses UM 8116 x UM 8301, UM 8116 x UM 8336 and UM 8116 x UM 8340 also gave highly resistant infection types to all the leaf rust cultures (Table 3). The remaining inbred lines UM 8003, UM 8071 and UM 8116 reacted differently to the different races of wheat leaf rust. The reactions varied from moderately resistant (infection types 2 to 2+) to susceptible types (infection types 3 to 3+).

Field Reaction

Table 4 shows the field reactions of the seven inbred lines. The results obtained indicate that all the inbred lines were resistant to both stem rust and leaf rust under field conditions. Reactions to leaf rust varied from trace reaction (TR) to moderately resistant (MR). The reaction to stem rust was similar. Only two inbred lines UM 8003 and UM 8336 gave variable reactions to leaf rust and stem rust rust and stem rust, respectively (Table 3). Inbred line UM 8116 which was used at the susceptible parent by Musa et al., (1984) was resistant under field conditions. This indicates that inbred line UM 8116 also possesses some field resistance.

DISCUSSION AND CONCLUSION

This study revealed that some inbred ryes have a broad spectrum of resistance to leaf rust of wheat and rye and to wheat stem rust. Two inbred lines UM 8336 and UM 8340 showed excellent resistance to both stem rust and leaf rust. These two inbred lines are potential sources of resistance to the rusts.

The seedling reactions to the formae speciales of stem rust indicate a high degree of physiologic specialisation in rye to rye stem rust but no evidence of physiologic specialisation was obtained in wheat stem rust. This is evidenced by the high resistant reaction types to stem rust. The differential reaction of the inbred ryes to leaf rust suggest the existence of physiologic specialisation in both wheat and rye leaf rust.

In the reaction to leaf rust, some inbred lines gave heterogeneous reactions on different plants. This suggests the possibility of heterogeneity for resistance in inbred lines UM 8003, UM 8116 which gave variable reactions to wheat leaf rust races 9 and 15, respectively. Similarly, F4 lines derived from the crosses UM 8116 x UM 8003, UM 8116 x UM 8071 and UM 8116 x UM 8295 also gave different reactions to to different races. Heterogeneous reactions to the same race were observed in this study. Tan et al., (1976) reported heterogeneous reactions in Wrens rye to *P. graminis secalis*. This is expected from the possibility of heterogeneity present in the parental inbreds. Rye is a cross pollinated species and a certain degree of heterogeneity would be present in some genotypes even after several generations of inbreeding although not after 7 to 12 years of selfing.

Results obtained from these tests indicate that the inbred ryes used in this investigation possess both seedling and adult plant resistance to leaf rust and stem rust. A combination of these resistances would offer an efficient method of controlling rust diseases in cereals.

It can be concluded that rye is a potential source of resistance to wheat pathogens. It is important that once resistant strains of rye are identified, they should be exploited through interspecific crosses. This would add to the genetic diversity of its closely related species of wheat and triticale. There is also a need to study the genetic relationship between seedling and adult plant resistance in rye in order to fully understand how this source of resistance could be fully utilised in combating cereal rusts.

ACKNOWLEDGEMENT

The author wishes to express his gratitude to Drs. Samborski, D. J. and P. L. Dyck for their stimulating interest and encouragements during the course of this study.

REFERENCES

ACOSTA, A. C. (1963). The transfer of stem rust resistance from rye to wheat. Diss. Abstr. 23: 34-35.

DRISCOLL, C. J., and JENSEN, N. F. (1964). Characteristics of leaf rust resistance transferred from rye to wheat. Crop Sci. 4: 372-374.

MAINS, E. B., and LEIGHTY, C. E. (1923). Resistance in rye to leaf rust, Puccinia dispersa Erikss. J. Agric. Res. 25: 243-252.

MAINS, E. B. (1926). Rye resistant to leaf rust, stem rust and powdery mildew. J. Agric. Res. 32: 201-221.

MOREY, D. D., (1956). Reaction of rye varieties to leaf rust, Plant Dis. Reptr. 43: 578-579.

MOREY, D. D., (1973). Rye improvement and production in Georgia. University of Georgia Expt. Station Research. Bull, 129: 38.

MUSA, G. L. C., DYCK, P. L. and SAMBORSKI, D. J. (1984). The inheritance of resistance in rye to Puccinia recondita f. sp. secalis and tritici Can. J. Plant Sci. 64: 511-519.

RAO, M. V. P. (1977). Transfer of genes for stem rust resistance from Agropyron elongatum and Imperial rye to durum wheat. In Induced Mutations Against Plant Diseases. Proceedings of a Symposium p. 527-531.

STAKMAN, E. C., STEWART, D. M. and LOEGERING, W. R. (1962). Identification of physiologic races of Puccinia graminis var. tritici. U.S. Dept. Agriculture. A.R.S. Bull. E617 (Rev.) Washington, D.C.

TAN, B. H., LUIG, N. H. and WATSON, I. A. (1976). Genetic analysis of stem rust resistance in secale cereale. I. Genes for resistance to Puccinia graminis f. sp. secalis. Z. Pflanzenzuchtung. 76: 121-132.

TABLE 1 - Seedling reaction of rye inbred lines to different races of wheat stem rust and isolates of rye stem rust

Inbred line	Parentage	Inbred Gen*	Wheat stem rust races			Rye stem rust races		
			C17	C53	C61	RSR44/78	RSR59/79	RSR101/80
UM8003	Petkus C.A.N. 1933	7	;	;	;	3+	-	1
UM8071	Self Fertile Profic	8	;	;	1	4	3+	4
UM8116	Self Fertile Spring	7	;	;	;	3+	2	4
UM8295	Gator/Brazil	12	;	;	-	-	-	1+
UM8301	Gator/Wrens	11	;	1	;	4	4	1
UM8336	Emory rye	11	;	;	;	;	;	;
UM8340	Hazel rye	11	;	;	;	1	;	1+

* Minimum number of generations selfed.

TABLE 2 - Seedling reactions of rye inbred lines to races of wheat leaf rust and an isolate of rye leaf rust

Inbred line	Wheat leaf rust races						Rye leaf rust
	5	9	15	30	76	126a	RLR 213/78
UM8003	2	0;-2	3+	2	3-3+	2+	2
8071	2	2	2+	2-2+	1+-2	2+	2+C
8116	2+	3+	2+-3+	3	3+	3+	3-3+
8295	0;1	0;	0;-0;1	;n	0;1	0;	0;1
8301	0;	0;	0;	0;	0;	0;	1+
8336	0;	0;	0;	0;	0;	0;	0;
8340	0;1-1+	0;1-1+	0;-0;1	0;1n	0;1	0;	0;

TABLE 3 - Seedling reactions of selected F4 lines to races of wheat leaf rust and an isolate of rye leaf rust

Selected lines	Wheat Leaf Rust Races						Rye Leaf Rust
	5	9	15	30	76	126a	RLR 213/78
UM8116 x 8003 - 27	3+	2-3	3+	3++	3+	O;	O;
- 29	3	2-3	2+	2+-3	3	2+	3+
- 32	3+	O;1-3+	3+	2+-3	3+	1	2+
37 - 2	2+	3	2	2	2-	O	2
UM8116 x 8071 - 16	3+	3	2+-3	2+	2-2+	3-3+	3+
- 17	2	2	1-1+	1+-2+	2	2++-3	3
18 - 1	2	2	1+	2-2+	1+	3+	3+
UM8116 x 8295 80-2	O;1-+	2	O;1	O;1	2	O;1-1+	O;1-1+
-99-1	2+	2	2+	O;1	2+	1	
UM8116 x 8301 -3	O;	O;	O;-O;1	O;1n	O;1	O;	O;
6-1	O;-1	O;	O;	O;	O;	O;	1+
9-1	O;	O;	O;	O;	O;	O;	1+
UM8116 x 8336-143	O;	O;	O;	O;	O;	O;	3
UM8116 x 8340 21-1	O;1-	O;	1+	O;1-	1+	O;	O;
24-1	O;	O;	O;	O;	O;	O;	O;

TABLE 4 - Adult plant reactions in the field of the inbred ryes at the Glenlea Rust Nursery in 1980

	Field Reaction	
Inbred Line	Leaf Rust	Stem Rust
UM8003	TR-50MR**	O
UM8071	TMR	10MR
UM8116	10MR	TR
UM8295	TR	10MR
UM8301	O	TMR
UM8336	O	TR-5 MS
UM8340	TR	30 M

O = No visible infection on plants

TR = Trace reaction

MR = Moderately resistant

M = Intermediate

MS = Moderately susceptible

** = Estimate of the relative percentage of rust infection

Cereal Rusts Bulletin Vol.13, Part 1, 1985

THE THIRD INDEPENDENT TRANSER OF THE Sr 35 GENE FROM TRITICUM MONOCOCCUM TO T. AESTIVUM

BY

J. VALKOUN, D. KUCEROVA AND P. BARTOS

Research Institute of Plant Production, Prague 6 - Ruzyne, Czechoslovakia

In the early 1970's two genes for resistance to wheat stem rust, Puccinia graminis f. sp. tritici, Eriks. et Henn. namely Sr 21 and Sr 22, were transferred from diploid wheats to hexaploid wheat, Triticum aestivum L. (The, 1973; Kerber and Dyck, 1973). Later, Valkoun and Bartos (1981) indicated the presence of three new additional genes for stem rust resistance, designated as Sr Tm_1, Sr Tm_2 and Sr Tm_3, in a collection of 60 accessions of cultivated einkorn, T. monococcum L. Inheritance studies in diploid wheats revealed that Sr Tm_1 and Sr Tm_2 were dominant and the third gene, Sr Tm_3 incompletely dominant (Valkoun et al, 1983). Recently, McIntosh et al. (1984) reported the simultaneous independent transference of a third stem rust resistance gene derived from diploid wheat in Australia and Canada and designated Sr 35. It is concluded that the accessions 2126/5 or 1509/2 described by Valkoun and Bartos (1981) could carry Sr 35. Using the same diploid donors of Sr 35 (C 69.69 and G 2919) as McIntosh et al. (1984) together with other diploid wheat accessions and after inoculation with 6 isolates of P. graminis it was concluded that Sr Tm_1 gene, which had been detected earlier in 13 accessions of the cultivated einkorn wheat (Valkoun and Bartos, 1981), was identical to that described Sr 35 (Valkoun et al., unpublished).

The accessions 1995 and 2126 of T. monococcum carrying the Sr Tm_1 (= Sr 35) gene were used as diploid resistance donors in the programme of wide hybridization in wheat carried out in the RIPP, Prague - Ruzyne. Selfed ear progenies of these accessions were crossed as male parents to the susceptible tetraploid T. durum accessions 3310 and 3574 or the hexaploid T. aestivum cvs. Chinese Spring and Zlatka (a Czechoslovak spring wheat). The tetraploid A A BD hybrids resulting from the direct crosses between hexaploids and diploids mostly either died in the juvenile phases of development or failed to produce normal reproductive organs or did not set seeds after backcrossing with the hexaploid parent. Therefore, the transfer programme continued only by means of triploid hybrids with genomic constitution A A B, the products of crosses between T. durum and T. monococcum. The triploid hybrids were completely male sterile but after pollination with the durum wheats a few seeds were obtained. One resistant 28-chromosome BC_1 plant derived from T. monococcum accession 2126 was selfed and several resistant plants of its progeny were pollinated with T. aestivum cvs. Zlatka and Jubilejnaja 50 (a Soviet winter wheat). The 35-

chromosome hybrids were backcrossed with the respective T. aestivum parents two to four times to obtain fertile stem rust resistant, 42-chromosome plants with good morphology and productivity. Some of these plants were selfed and gave rise to non-segregating resistant hexaploid lines. No irregularities in the gametic transfer of Sr 35 in advanced generations of the backcrossing were observed. The level of adult plant resistance expressed in infection types (IT) in all the hexaploid derivates carrying Sr 35 was distinctly lower (IT = 2+) in comparison with the diploid donor of the resistance gene (IT = 0), whereas in the seedling stage the decrease of resistance with higher ploidy was negligible (IT = 0 to 1). McIntosh et al. (1984) found very low infection types obtained with avirulent strains at the hexaploid level in adult plants carrying Sr 35. The disagreement between their results and our findings may be explained by effects of genetic background of the T. aestivum recurrent parent and/or by difference in quality and quantity of the genetic material transferred together with the Sr 35 gene from T. monococcum and T. durum. The effect of different rust races also cannot be excluded. Sr 35, the third gene derived from T. monnococcum, proved to be more effective against the Czechoslovak population of P. graminis f. sp. tritici than Sr 21 and Sr 22, because no virulence was detected among isolates of races 14, 21, 34 and 11. The only case of virulence on Sr 35 was detected in an older isolate of the rare physiological race 294. On the basis of the previous findings it is believed that the Sr 35 resistance gene may be employed in Czechoslovakia and perhaps in other European countries in wheat breeding for resistance to stem rust, without combination with other genes unlike Australia and Canada (McIntosh et al. 1984). Therefore, the breeding value of the Sr 35 gene may differ in various geographical regions. The technique of gene transfer from T. monococcum to T. aestivum through the triploid AAB hybrid recommended by The and Baker (1975) has proved to be effective because three genes for resistance to P. graminis f. sp. tritici Sr 21, Sr 22 and Sr 35) and one very effective gene conferring resistance to P. recondita (Valkoun et al., 1985) have been transferred by this method.

ACKNOWLEDGEMENTS

The authors wish to thank Drs. R. A. McIntosh, Plant Breeding Institute, University of Sydney, Australia and P. L. Dyck, Agricultural Canadian Research Station, Winnipeg, Canada, for kind supply with the seed of their diploid donors of Sr 35, C 69.69 and G 2919, respectively. The accessions 1995 and 2126 of T. monococcum and 3310 and 3574 of T. durum, used in this study, were obtained by the courtesy of Drs. Ch. Lehmann and K. Hammer, Zenntralinstitut fur Genetik und Kulturpflanzenforschung, Gatersleben, GDR.

REFERENCES

KERBER, E. R. and P. L. DYCK (1973) - Inheritance of stem rust resistance transferred from diploid wheat Triticum monococcum to tetraploid and hexaploid wheat and chromosome location of the gene involved. Can. J. Genet. Cytol. 15: 397-409.

MCINTOSH, R. A., DYCK, P. L., THE, T. T., CUSICK, J. and D. L. MILNE (1984) - Cytogenetical studies in wheat XIII. Sr 35 - a third gene from Triticum monococcum for resistance to Puccinia graminis tritici. Z. Pflanzenzuchtung 92: 1-14.

THE, T. T. (1973) - Chromosome location of genes conditioning stem rust resistance transferred from diploid to hexaploid wheats. Nature New Biology 241: 256-257.

THE, T. T. and E. P. BAKER (1975) - Basic studies relating to the transference of genetic characters from Triticum monococcum L. to hexaploid wheat. Aust. J. Biol. Sci. 28: 189-199.

VALKOUN, J. and P. BARTOS (1981) - Wheat stem rust resistance in diploid wheats. Cereal Rusts Bulletin 9: 27-32.

VALKOUN, J., BARTOS, P. and KUCEROVA, D. (1983) - The inheritance of stem rust resistance of cultivated einkorn (Triticum monococcum). (In Czech with Engl. sum.) Sbor. UVTIZ - Genet. a Slecht., 19:179-184.

VALKOUN, J., KUCEROVA, D. and BARTOS, P. (1985) - Transfer of leaf rust resistance from Triticum monococcum L. to hexaploid wheat (in press).

Papers, short notes on topics such as Pathogen Virulence surveys, Breeding for resistance, Sources of resistance, Control of cereals rusts, Techniques or any subject of possible interest to other rust workers are required for the Bulletin.

Papers - typed double spaced should be sent to:

Dr N H Chamberlain

Nickerson RPB Ltd

Joseph Nickerson Research Centre

Rothwell

Lincoln

LN7 6DT

Great Britain