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Role of Mixed Cultivars in Disease Management

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Sourik Poddar[1]

[1]Dept. of Genetics and Plant Breeding, Uttar Banga Krishi Vishwavidyalaya, Pundibari-736165, Coochbehar, West Bengal, India.

Introduction

The grounds responsible for severe epidemic in agriculture is the norm of growing homogeneous monoculture crops Browning et al., (1988). It has already been reviewed that the use of diversity (mixtures, multiline etc) for effective disease management for economic plants Browning et al., (1969), Frey et al., (1969) and Wolfe et al., (1985) and a positive relation has been established Browning et al., (1989). First experiment on multiline and mixtures for disease control dates more than 40 years ago. Management of diseases like powdery mildew and rust on cereals are well researched Wolfe et al., (1985). An important point to be stressed upon is Functional Diversity. The principle governing the Functional Biodiversity is the use of cultivars with diversified functions for limited disease development Schmidt et al., (1978).

Cultivar mixtures is defined as to use cultivated variety mixtures growing together at the same plot with no need to breed for phenotypic uniformity Mundt et al., (2002). Its use is more practical than multiline due to no need to breed new cultivar and can be easily implemented by farmers of developing countries. Mixed populations are more resistant to unfavourable environments like- biotic and abiotic stress Wolfe et al., (2005); Wolfe et al., (1990); Wolfe et al., (1997).

Disease Reduction Mechanism

Different such mechanisms are explained in different review articles Mundt et al., (2002):

1. Dilution Effect: Defined as reduction in disease due to increased distance between susceptible cultivars in a mixture Browning et al., (1969), Frey et al., (1969); Chin et al., (1984) and Wolfe et al., (1984). Resistant cultivar is accountable for decrease inoculum production from the susceptible cultivars.

2. Barrier effect: Responsible for movement limitation of inoculum from susceptible cultivar due to physical barrier provided by resistant cultivars Browning et al., (1969) and Frey et al., (1969).

3. Induced resistance: It occurs when the defence mechanism of a resistant plant is activated by a non-virulent race of the pathogen Lannou et al., (1995), Chin et al., (1984) and Wolfe et al., (1984). Especially for rust and powdery mildew of wheat Van Asch et al. (1992) and also on saprophytic fungi on small grains Gregersen et al., (1989)

4. Competition among pathogen races: Diversity of pathogen is more than in the monoculture, thus there is more interaction and competition between the pathogen races Garrett et al., (1999) and Mundt et al., (1999). This leads to suppression of some races, and there is less disease in the mixture.

Works Done Using Mixed Cultivars

The genetic divergence increased by using mixed cultivars, show a positive result on disease suppression in different plant pathosystems Zhu et al., (2000) and Finckh et al., (2008). A mixture composed of five wheat cultivars, Jingdong 8, Jingshuang 16, Lunxuan 987, Jing 411, and Baofeng 104, was used and the result supported such observation. Different control efficiency was shown by different composition but some showed negative impact on wheat yield Ning et al., (2012). Important point raised Mundt et al., (1995) that efficiency of mixture may be reduced by artificial inoculation which increases the strength of inoculum. Moreover, artificial inoculation does not ensure the evenness of the disease occurrence in the field although it can ensure the occurrence of the disease Finckh et al., (1992) and Mundt et al., (1992).

The efficiency of host diversity is more when the host genotype unit area (GUA) is small, presence of strong host specialization, low pathogen dispersal gradient, lesion characteristic size is small, number of pathogen generation is large. Wind dispersal pathogen are more effectively reduced than the splash dispersal pathogens Garrett et al., (1999) and Mundt et al., (1999). The favourable environment plays a vital role in efficiency of mixture for reduced disease in a particular year and location as Mundt et al., (1995) was not able to detect reduction in eyespot severity in wheat mixture but Vilich-Meller et al., (1992) reported substantial reduction in barley and wheat mixtures in Germany.

The efficiency of mixing was more in leaf rust than tan spot of wheat in Great Plain when two cultivar named Jagger which is moderately resistant to tan spot and susceptible to leaf rust, and 2145 which is resistant to leaf rust and susceptible to tan spot used in proportion of 0.25,0.5,0.75,1.00 was observed Cox et al., (2004) and Garrett et al., (2004). The relationship between plant genotypes induces more complexity and unpredictability to relationship between yield and disease severity in mixture Finckh et al., (2000).

An experiment using 5 varieties of spring barley (Skarb, Blask, Antek, Basza and Rubinek), differentially resistant to barley powdery mildew showed an effective result of cultivating mixtures of spring barley in terms to resistance to powdery mildew (B. graminis f. sp. hordei) and yield increase Tratwal et al., (2017). The addition of biodiversity and features of particular plants which allows a better use of environmental resources without disturbing its biological balance is the greatest advantage of using mixed cultivars. An increased distance between plants with the same genetic resistance to diseases, restriction of pathogen spread by resistant plants which form a natural barrier, competitive interactions among host plants affecting their disease susceptibility is of great importance in disease management Finckh et al., (2000).

By 1980s, barley cultivar mixtures were used in then German Democratic Republic to control powdery mildew in the areas where severity has reached 50%. The percentage of field under mixed cultivar rose to 92% by 1990, while the severity declined to 10% and the field sprayed with fungicides reduces threefold. Similar effect was not observed in the areas where such diversification did not prevail Wolfe et al., (1992).

Leonard et al., (1969) proposed a classical model of host diversity efficiency on disease, in which, a single pathogen genotype in simple mixtures of one susceptible and one immune plant genotype. This model shows that severity of disease decrease logarithmically as resistant plants gets added in the mixture. This was again established by Mundt et al., (1985) and Browning et al., (1985).

Spatial Refinements to the Classic Model

Autoinfection: Robinson et al., (1976) described it as the amount of pathogen inoculum present on the same host plant on which it was produced. The degree of autoinfection depends upon interaction between pathogen dispersal gradient and single host plant size. High dispersal gradient results in small host diversity effect on disease. The GUA plays a vital role in determining the nature of a host-diversity effect on disease. If GUA increase through higher aggregation then the effect of diversity on disease is less Mundt et al., (1986) and Leonard et al., (1986). In studies of Puccinia coronata on oat mixtures have proved it Mundt et al., (1985) and Browning et al., (1985).

Lesion Expansion and Limits to the Host's Carrying Capacity for Disease: A study conducted on stripe rust and leaf rust of wheat, if environment and pathogen generation time are constant, then the lesion expansion of stripe rust decreased host diversity effects for reduced disease by half compare with leaf rust Lannou et al., (1994).

Genetic Refinement to the Classic Model

Race-Nonspecific Differences in Resistance of Host Genotypes: In a mixture of genotypes with varying race nonspecific resistance, efficiency of host diversity will depend on whether the disease decrease on the more susceptible cultivar is greater than the disease increases on the more resistant cultivar. Different host diversity has been experienced in different mixture compositions Jeger et al., (1981).

Race-Specific Differences in Resistance of Host Genotypes: Calonnec et al., (1996) estimated that one-third of the decrease in infection by Puccinia striiformis in wheat mixtures was because of induced resistance. Interconnection between pathogen races may also affect host diversity effect. This may lead to decreased disease severity in some pathosystems Newton et al., (1997)

Compensation and Competition: Wheat genotypes mixtures infected with Puccinia striiformis, Finckh et al., (1992) and Mundt et al., (1992) concluded that increased tillering of the resistant genotype sometimes results for very considerable amount of the total disease reduction in mixtures. Genotype competition within mixtures also may alter the susceptibility of a given host genotype, changing host-diversity effects for disease.

Resistance gene combinations and some mixtures has potential to increase the effectiveness of resistance genes. Gene blending were more effective than mixtures for the limited number of populations tested in a study of 9 varieties of rice against bacterial blight of rice Hafiz et al., (1997).

Conclusion

Designing a system using mixed cultivars is a dynamic process. Customization is required not only for disease but also to various biotic constrains and cropping pattern of some specific area. Some research issues are- what cultivar combinations should be used? What are of the effect of different compositions on biotic constrains and productivity? What are the mechanisms for disease control and increase yield by these different compositions of mixtures? Some important points that should be kept in mind while using cultivar mixtures – is it reliable for marginal framers? Etc. The expansions made in fields of genomics and phenotyping allow effective selection of cultivars against pathogen population of specific location Castilla et al., (2003).

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