Pak. J. Agri. Sci., Vol. 56(2), 339-344; 2019
ISSN (Print) 0552-9034, ISSN (Online) 2076-0906
DOI: 10.21162/PAKJAS/19.6914
http://www.pakjas.com.pk

ROW SPACING AS A STRETEGY TO CONTROL BACTERIAL LEAF BLIGHT IN DIRECT SEEDED FINE RICE

Muhammad Asim Rashid[1,*], Nadeem Akbar[1], Riaz Ahmed[1] and Amer Habib[2]

[1]Department of Agronomy, University of Agriculture, Faisalabad, Pakistan; [2]Department of plant pathology, University of Agriculture, Faisalabad, Pakistan
[*]Corresponding author's e-mail: bioworld3030@gmail.com

Bacterial leaf blight (BLB) is one of the most important diseases that limit overall rice productivity. To investigate the effects of row spacing on incident of bacterial leaf blight (BLB) in rice, field experiments were conducted at Agronomic Research Area, Department of Agronomy, University of Agriculture Faisalabad during 2013 and 2014. Two rice cultivars i.e., Super Basmati (V_1) and Basmati-515 (V_2) were sown at three different row spacings i.e., 15, 22.5 and 30 cm regarded as S_1, S_2, and S_3, respectively. Results depicted that the lowest disease incidence i.e., 4.00 and 4.09% was recorded for Basmati-515 sown at 30 and 22.5 cm apart rows, respectively. The maximum productive tillers m^{-2} was recorded in V_1S_2, whilst the panicle length, kernels per panicle, and normal kernels per panicle were recorded in V1S3. The 1000 grain weight was found highest in V_2S_2. The maximum paddy yield i.e., 3.99 t ha^{-1} was recorded in V_1S_2 which were statistically similar to V_2S_2, whereas the harvest index was also found significantly higher in V_2S_2 than all other interactions. Among both rice cultivars, Basmati-515 was found less prone to BLB as compare Super Basmati. Hence, wider row spacing significantly reduced bacterial leaf blight severity. Thus, it can be concluded that BLB can be managed by growing early maturing short duration genotypes at wider row spacing.
Keywords: Aerobic fine rice, BLB, crop row spacing, economic yield, % DLA.

INTRODUCTION

Rice is a very important crop for the humanity as it feeds more than 50% population of the world (Zhang and Xie, 2014). It plays an important role in strengthening the economy of the country by earning a lot of foreign exchange. Its share in Pakistan's export is 6.5 (GOP, 2017). Though Pakistan is known world over for its fine Basmati rice having unique aroma and good taste, yet its production is very low as compared to many other rice growing countries. Rice was grown on an area of 2.72 million hectares with a total production of 6.84 million tons producing an average yield of 2.51 t ha^{-1} (GOP, 2017). A huge gap exists in the potential and actual economic yield between research station and progressive farmer's average production, as this average yield is substantially low. This yield gap between potential and actual yield at farmer's field is attributed to several agronomic constraints such as manual planting methods, poor weed control practices, sub optimal plant population, imbalance fertilizer use and disease outbreak especially bacterial leaf blight.

Generally, direct seeded rice cultivation is prone to similar pests and diseases as flooded rice. Nevertheless; there might be greater chances of outbreak of insect-pests and diseases in direct seeded rice with high plant densities. To enable farmers to reap the full benefits of aerobic rice and achieve sustainable crop management, focused efforts are required in developing ecological approaches to pest management and increasing information availability at farm level (Soriano and Reversat, 2003). Bacterial blight is the major disease of both puddled and aerobic rice cultivation. Crop microclimate is directly affected by water application especially the dew deposition, as in terms life cycle of the pathogens is affected directly (Sah and Bonman, 2008) and hence crop physiological growth is affected indirectly, thereby influencing host vulnerability (Bonman, 1992). The greater threat of brown spot disease and plant hoppers in aerobic rice compared with flooded rice has been reported (Savary *et al*., 2005).

Rice blight is one of the most important and widely distributed bacterial diseases of rice in the world. Bacterial leaf blight was reported in Japan and Philippines almost 75 years ago (Myint *et al*., 2007). It has been stated that bacterial leaf blight (BLB) is increasing in Pakistan in recent years especially in Kallar belt that is a genuine homeland for producing high quality Basmati rice (Khan *et al*., 2000). Each year rice diseases destroy rice crop enough to feed 60 million people and cause farmers a loss of $5 billion in Pakistan (Asghar *et al*., 2007).

Since the past few decades, the use of pesticides to manage crops pests has amplified considerably that resulted in a serious risk to environment and human health (Zafar *et al*., 2010). The control of BLB is very important as far as chemical control is concerned, it is costly and causes environmental hazards and more over resistance against applied chemical in pests in now a day a major problem. Cultural practices such as fertilizer rate, sowing time and irrigation played an important role for the control of diseases (Myint *et al*., 2007; Nino-Liu *et al*., 2006). Khan *et al*. (2002) reported that most of the Basmati rice cultivars cultivated in the country are susceptible to diseases. Super basmati is a widely used variety in Pakistan but is severely susceptible to BLB incidence. The only feasible and economical way of controlling disease is the use of resistant rice cultivars. Lore *et al*. (2011) reported that breeding of rice varieties with durable resistance to pathogens is most logical and friendly approach. As in existing conditions commercial resistant varieties are generally scarce. Therefore, searching of disease resistant rice varieties against bacterial leaf blight of rice are necessary approach to be followed.

Rice blight can be efficiently managed by balanced use of fertilizers, proper row spacing and suitable rotation (IRRI, 2003). Sheath blight disease in incidence in rice fields is dependent on the method of planting and plant population density (Kumar *et al*., 2009). Plant spacing directly affects the normal physiological activities through intra-specific competition (Oad *et al*., 2001). The square method of transplantation can decrease the relative humidity and temperature below the crop canopy as well as increase evapotranspiration and sunlight penetration, resulting unfavorable environment for sheath blight disease development and higher grain yield (Yang *et al*., 2008). The incidence chances of aschochyta bight is increased with higher plant densities, due to more contact injury and lower chances of inoculums being lost to the soil (Chang *et al*., 2007). Epidemiology of various crop diseases can be altered with suitable crop density (Regan *et al*., 2003; Chang *et al*., 2005). Therefore, our objectives of the present study were to quantify suitable genotypes against various row spacings and their conjunctive impact on rice BLB, yield and yield contributing factors.

MATERIALS AND METHODS

A research to study the agronomic strategies to manage BLB in direct seeded aerobic rice was conducted on sandy clay loam soil at Agronomic Research Area, Department of Agronomy, University of Agriculture Faisalabad during 2013 and 2014 comprised of two factors genotypes (Super Basmati and Basmati-515) and sowing distance (15, 22.5 and 30 cm) following Randomized Complete Block Design under the spilt plot arrangements having the rice cultivars in main plots and row spacing in sub plots using 2.25 m × 6.0 m net plot size. The crop was direct seeded with the help of hand drill in the fine prepared field. A seeding rate of 35 kg ha^{-1} was used. To protect the rice crop from seed borne diseases, seed was treated with fungicide Topsin-M (Thiophanate methyl) at 2 g kg^{-1} of seed. Fertilizer was applied at 133- 85-62 kg NPK ha^{-1}, respectively. Whole of the potash, phosphorus and 1/3 of nitrogen was applied at sowing. Remaining nitrogen was applied in two doses i.e. tillering and panicle initiation. The weeds were controlled through manual labor by hand weeding as and when needed. However, they were eliminated by hand pulling and by use of weedicides. There were also symptoms of zinc deficiency. For this purpose zinc sulphate (21%) was applied at 25 kg ha^{-1}. An attack of the leaf folder and stem borer was also seen on the rice crop, therefore, granular insecticide, Carbafuran at 20 kg ha^{-1} was applied twice in the season to control these insect pests. The rice crop leaves were infected with *Xanthomonas oryzae* pv. *oryzae* at the time between rice tillering stage and heading stage by clipping method (Ke *et al.*, 2017). The concentration of inoculated spore suspension for *X. oryzae* was 10^8 cfu/ ml. The clipping method was used for inoculation with the help of dipped scissors. Leaf tips (2-3 cm) were cut and then dipped into the suspension. Data regarding incidence of BLB of rice was started one month after sowing up to physical maturity of crop on weekly basis. At maturity, morphological and yield parameters were measured from all the plots. Percent disease incidence (BLB) was also computed using disease rating scale (Table 1) devised by IRRI (1996). Disease incidence was computed using the formula given below:

Disease incidence (%) = (Total lesion length) / (Total leaf length) × 100

Computer package MSTAT-C and Fisher's ANOVA technique was applied to test the overall analysis and significance of the data (Steel *et al.*, 1997). Difference among the treatment means were compared using least significant difference test at 5 % probability level.

Table 1. Disease rating scale for bacterial leaf blight of rice (IRRI, 1996).

Percent area	Response	Ranking
0	Highly resistant	0
0-1	Resistant	1
1-5	Moderately resistant	3
6-25	Moderately susceptible	5
26-50	Susceptible	7
51-100	Highly susceptible	9

RESULTS

In the present study we measured different parameters regarding percent diseased incidence (% DLA), quality parameters, productive tillers, kernels per panicle, panicle length, 1000-kernel weight, paddy yield and harvest index. There parameters were markedly influenced by interactive effect of varieties and row spacing. Further, we found same trend in our data during both years.

Data indicated that interaction between both genotypes and row spacing for bacterial leaf blight incidence was significant (Table 2). Data comprised on mean of BLB incidence after seedling stage, maximum tillering stage and leaf flag stage illustrated that a minimum disease leaf area (DLA) was observed (15.81%) for Super Basmati when sown on 30 cm

Table 2. Percent disease incidence (% DLA) and agronomic parameters as affected by fine rice genotypes sown at various sowing distance.

Treatment		BLB incidence (% DLA)	Productive tillers (m^{-2})	Panicle length (cm)	Kernels per panicle	Normal kernels per panicle	1000-kernel weight (g)	Paddy yield (t ha^{-1})	Harvest index (%)
Varieties	Super Basmati (V_1)	31.73a	270.72	21.54a	96.55a	57.77b	18.80b	2.97b	23.16
	Basmati-515 (V_2)	18.77b	243.44	18.50b	83.72b	59.50a	20.17a	3.44a	24.20
	LSD value	1.15	35.23	0.38	3.94	0.86	0.17	0.06	0.97
Sowing distance	15 cm (S_1)	51.47a	164.58c	15.71c	73.25c	46.50c	17.57b	2.33c	21.64b
	22.5 cm (S_2)	14.33b	353.17 a	21.30b	93.17b	63.16b	20.47a	3.96a	23.93a
	30 cm (S_3)	9.95c	253.50b	23.04a	104.00a	66.25a	20.41a	3.32b	23.47a
	LSD value	2.82	14.97	0.69	1.68	3.06	0.23	0.04	0.75
Varieties × Sowing distance	V_1S_1	59.36a	173.83d	16.94d	78.00d	45.66c	16.50e	1.75e	21.86c
	V_1S_2	20.04c	372.33 a	22.49b	100.67b	61.50b	19.45c	3.99a	24.49b
	V_1S_3	15.81d	266.00c	25.18a	111.00a	66.16a	20.46b	3.17c	23.14b
	V_2S_1	43.58b	155.33d	14.48e	68.50e	47.33c	18.64d	2.91d	22.43b
	V_2S_2	8.63e	334.00b	20.10c	85.67c	64.83ab	21.50a	3.93a	25.45a
	V_2S_3	4.09f	241.00c	20.91c	97.00b	66.33a	20.36b	3.48b	24.73b
	LSD value	4.00	21.18	0.98	2.38	4.32	0.32	0.07	1.07

Any two means not sharing a letter in common in a column differ significantly at $p \leq 0.05$.

distance. However, maximum DLA (59.36%) was noted when row spacing was15 cm apart. Similarly, rice genotype Basmati-515 which was less prone to BLB showed complete resistance against bacterial leaf blight when sown apart. Genotype Basmati-515 showed 43.58% DLA when planted 15 cm apart, however, a minimum DLA (4.09%) was observed when crop was harvested 30 cm followed by 8.63% disease score at 22.5 cm row spacing, respectively. Means of genotypes across row spacing expressed that minimum DLA was noted when genotypes were sown apart.

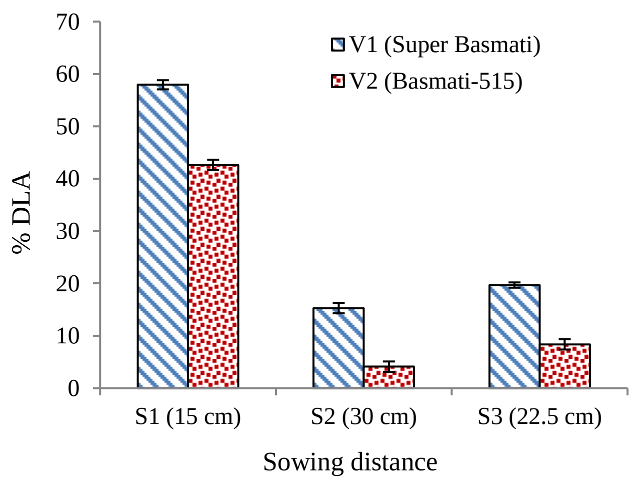

Figure 1. Bacterial leaf blight incidence (% DLA) as affected by varieties and sowing distances in 2013.

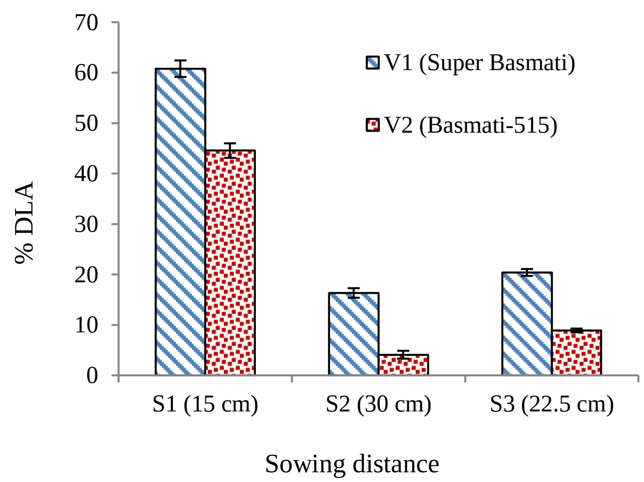

Figure 2. Bacterial leaf blight incidence (% DLA) as affected by varieties and sowing distances in 2014.

Data revealed that panicle bearing tillers were significantly affected by various genotypes and row spacing. The ability of both fine rice genotypes to produce panicle-bearing tillers was exaggerated significantly with different row spacing. Super Basmati showed maximum number of panicle bearing tillers. Super Basmati gave maximum panicle bearing tillers m^{-2} (372.33) when sown in 22.5 cm apart followed by 30 cm apart row spacing valued (266.00), respectively.

The same rice variety showed minimum number of panicle bearing tillers m^{-2} **(**173.83) when sown at 15 cm apart. Similarly, Basmati-515 produced maximum panicle bearing tillers m^{-2} (334.00) when sown 22.5 cm apart followed by 30 cm apart row spacing which gave 241.00. While, genotype Basmati-515 showed minimum number of panicle bearing tillers m^{-2} **(**155.33) when sown at15 cm apart

Data revealed that effect of different rice genotype and row spacing on panicle length was statistically significant. A gradual increase in panicle length was found by succeeding row spacing. Super Basmati showed maximum panicle length (25.18 cm) when direct seeded at 30 cm row spacing followed by 22.5 cm row spacing (22.49 cm) and 15 cm row spacing **(**16.94 cm**)**. Genotype Basmati-515 showed maximum panicle length (20.91) when direct seeded at 30 cm row spacing, while 15 cm row spacing rice cultivation produced minimum number of panicle length (14.48 cm). While comparing both genotypes, Super Basmati showed more panicle length under all row spacing (Table 2).

The interaction between different fine rice genotypes and row spacing for producing the number of kernels per panicle was statistically significant. Maximum number of kernels per panicle (100.67) was recorded from genotype Super Basmati when planted on 30 cm which was statistically differed with other planting distances. While, minimum kernels per panicle (78.00) were observed in Super Basmati when planted 15 cm apart. On the other hand, maximum kernels were counted for genotype Baasmati-515 (97.00) when row spacing was 30 cm. However, minimum number of kernels (68.5) was counted when this genotype was planted on 15 cm. Contrasting both genotypes, Super Basmati produced more number of kernels as compared to Baasmati-515 under all row spacings (Table 2).

Row spacing along with different genotype affected the normal kernels (%) significantly. Data expressed that higher number of normal kernels (66.16) was calculated for genotype Super Basmati when row spacing was 30 cm. While minimum normal kernels was noted (45.66) when row spacing was 15 cm. Similar trend was observed in other genotype Basmati-515 which showed maximum number of normal kernels (66.33) when row spacing was 30 cm. While minimum normal kernels in Basmati-515 were counted (47.33) when row spacing was 15 cm. While comparing both genotypes, Basmati-515 showed more normal kernels as compared to Super Basmati under at row all row spacings (Table 2).

Data regarding influence of varieties, row spacing and their interaction on 1000 kernel weight was found statistically significant (Table 2). Data delineated that both genotypes responded differently to various row spacing for 1000 kernels weight which was statistically significant for three respective row spacings (Table 2). Means of row spacing across genotypes expressed that genotype Super Basmati showed maximum weight for 1000 kernels (20.46 g) when direct seeded on 30 cm. While minimum 1000 kernel weight (16.50 g) Super Basmati was observed when planted on 15 cm. Moreover, Basmati-515 showed maximum 1000 kernel weight (21.50 g) when planted on 22.5 cm and minimum 1000 kernels weight (18.64 g) was found when row spacing was 15 cm. Among both genotypes, Basmati-515 showed higher 1000 kernels weight as compared to Super Basmati under all row spacings (Table 2).

Results indicated that genotype Super Basmati produced maximum paddy yield (3.99 t ha^{-1}) when direct seeded on 22.5 cm (Table 2). However, this genotype gave minimum paddy yield (1.75 t ha^{-1}) when planted 15 cm apart. It was found that paddy yield (t ha^{-1}) was gradually increased by increasing the row spacing. Moreover, Basmati-515 gave maximum paddy yield (3.93 t ha^{-1}) when planted on 22.5 cm; however, a minimum paddy yield (2.91 t ha^{-1}) in this genotype was recorded when sowing distance was 15 cm. While comparing both genotypes, Basmati-515 showed higher paddy yield at both row spacing i.e. 15 and 30 cm. While, there was no significant difference in both genotypes when planted at 22.5 cm (Table 2).

Data expressed that superior harvest index (25.94) was noted for genotype Super Basmati when planted on 22.5 cm which was statistically at par with 30 cm sowing distance respectively. While minimum harvest index (15.46) in this genotype was noted when planted at 15 cm. Genotype Basmati-515 also showed maximum harvest index (38.54) when sown on 22.5 cm, while minimum harvest index (32.51) was observed when Basmati-515 was planted on 15 cm. When we compare both genotypes, Basmati-515 showed higher harvest index at both row spacing i.e. 15 and 22.5 cm. While, there was no significant difference in both genotypes when planted on 30 cm (Table 2).

DISCUSSION

Bacterial leaf blight (BLB) of rice occurrence is remained high in Punjab during Sep.- Oct. due to strong winds (disease susceptible environment) (Akhtar *et al*., 2003). However, it has been reported that most of Basmati rice cultivated genotypes in the country are susceptible to diseases (Khan *et al*., 2002). Direct seeded aerobic rice matures earlier than transplanted rice. So this menace could be managed by searching the optimum row spacing as aerobic rice can be less prone to BLB. Plant spacing directly affects the normal physiological activities through intra-specific competition. The wider plant spacing can decrease the relative humidity and temperature below the crop canopy as well as increases evapotranspiration and sunlight penetration, resulting unfavorable environment for diseases and results higher grain yield (Yang *et al*., 2008). The present study showed that genotype Basmati-515 showed resistance against BLB when planted at 30 cm and 22.5 cm; while, Super Basmati was highly susceptible to BLB at all row spacing. Further, results showed that by reducing the row spacing both genotypes were more vulnerable to BLB. Genotype Basmati-515 showed more resistant to BLB due to the reason that it is an early maturing short duration genotype and having growth patterns just like coarse varieties; because coarse varieties are less vulnerable against BLB. These findings are in line with Khaing *et al*. (2015) who concluded that enhanced planting density increased the sheath blight disease. Further, they found that wider row spacing reduced the disease outbreak. Moreover, Zhong *et al*. (2006) and Wu *et al*. (2014) also stated that sheath blight index decreased by increasing plant spacing. Similarly, Wu *et al*. (2014) found no difference in sheath blight resistance based on disease lesion development according to plant spacing. Previously, it was concluded that sheath blight disease in rice fields is dependent on the method of planting and plant population (Kumar *et al*., 2009: Oad *et al*., 2001).

The increased number of panicle bearing tillers under wider row spacing was due to the fact that rice sown at wider row spacing had longer period of vegetative growth compared to those closely spaced. Similarly, closely spaced varieties might have faced more disease at panicle bearing stage which resulted in less panicle bearing tillers. Agronomic management strategies as fertilizer and planting density have significant influence on growth parameters of crop especially tillering intensity which in terms affects the canopy structure (Wu *et al*., 2014) which determine contact frequency-a necessary requirement for pathogen and disease proliferation (Willocquet *et al*., 2000; Wu *et al*., 2014). Hence, planting density induces more contact frequency and as a result more disease incidence (Wu *et al*., 2014). Previously, Khaing *et al*. (2015) reported that wider rows significantly affected the number of productive tillers. This study, therefore, revealed the influence of BLB disease on fertile tillers per m^2.

The physiological activities of the crop are directly affected through intra-specific competition due to row and plant spacing (Oad *et al.*, 2001). Planting density (spacing) has a significant effect on productive tiller, normal kernel percentage and 1000-kernel weight (Khaing *et al*., 2015; Mondal *et al*., 2013). In our study, reason for longer panicles in plots where rice was sown at 22.5 cm and 30 cm spaced rows was that rice plants got more nutrients and moisture from soil, thus roots might have penetrated deep and so they exploited the soil fertility efficiently which resulted in longer panicles. Previously, Lu and Cai (2000) also concluded that 1000-kernel weight was decreased by decreasing the planting density. This shows that the environmental conditions like temperature, humidity are most favorable for grain development for wider rice cultivation as compared to closely spaced rice. While, in case of 15 cm sown aerobic rice, the crop was prone to more BLB incidence, so due to more disease virulence this might induced the stress to the crop. Similarly, Khaing *et al*. (2015) suggested that optimum row spacing is a crucial factor which affects the yield and yield contributing factors by altering the epidemiological conditions which are necessary to induce the disease.

Agronomic strategies such as fertilization and plant spacing are environment friendly approaches as sheath blight incidence could be reduced by adopting wider row spacing and low nitrogen use. In our study, intermediate row spacing (22.5 cm) produced higher paddy yield in both genotypes (Table 2). It is considered that proper crop spacing resulted in lower contact frequency accompanied by higher yield as a result of better disease management (Wu *et al*., 2014). Our findings are similar with Mondal *et al*. (2013) where paddy yield was increased with increase in plant spacing. Khaing *et al*. (2015) also concluded that wider spacing significantly influenced the economic yield as row spacing significantly affected productive tillers, 1000-kernel weight, kernels per panicle. The higher paddy yields at 22.5 cm row spacing might be due to greater number of fertile tillers $hill^{-1}$, kernels per panicle, number of branches per panicle and 1000-kernel weight obtained in plots sown at this row spacing. However, lower paddy yields in case of closely spaced rice might be due to lesser number of tillers, kernels per panicle and shorten panicle length which diminished paddy yield. Declined yield might also be superimposed due to increased BLB in case of closely spaced rice genotypes, due to increased BLB attack on panicles and resulted in lesser kernel per panicle and in terms paddy yield.

***Conclusion*:** In the present study we found that row spacing 22.5 cm produced less BLB incidence in both genotypes. So alternatively, maximum panicles length, kernels per panicle, paddy yield and harvest index was observed at this row spacing. There we concluded that direct seeding of rice at row spacing of 22.5 cm is essential. Vulnerability of genotypes to BLB incidence is increased when closely sown at 15 cm row spacing. Thus, BLB can be managed by growing early maturing short duration genotypes which are less prone to disease incidence as Basmati-515.

REFERENCES

Akthar, M.A., M. Zakria, F.M. Abbasi and M.A. Masood. 2003. Incidence of bacterial blight of rice in Pakistan during 2002. Pak. J. Bot. 35:993-997.

Asghar, A., H. Rashid, M. Ashraf, M.H. Khan and A.Z. Chaudhary. 2007. Improvement of basmati rice, against fungal infection through gene transfer technology. Pak. J. Bot. 39:1277-1283.

Bonman, J.M.1992. Durable resistance to rice blast disease-environmental influences. Euphytica 63:115-123.

Chang, K. F., H.U. Ahmed, S.F. Hwang and R.J. Howard. 2005. Manipulation of row spacing and seeding rate for the management of ascochyta blight of chickpea. Can. J. Plant Pathol. 27:145-146.

Chang, K. F., H.U. Ahmed, S.F. Hwang, B.D. Gossen, R.J. Howard, T.D. Warkentin, S.E. Strelkov and S.F. Blade. 2007. Impact of cultivar, row spacing and seeding rate on ascochyta blight severity and yield of chickpea. Can. J. Plant Sci. 87:395-403.

Anonymous. 2017. Economic survey of Pakistan. 2016-17. Ministry of Food, Agriculture and Livestock Division (Economic Wing), Govt. of Pakistan, Islamabad, Pakistan; pp.22-23.

IRRI. 1996. Standard evaluation system for rice, 4th Ed. INGER, Genetic resources Centre IRRI, Manila, Philippines.

IRRI. 2003. Rice Doctor. International Rice Research Institute, Manila, Philippines.

Ke, Y., S. Hui and M. Yuan. 2017. *Xanthomonas oryzae* pv. *oryzae* inoculation and growth rate on rice by clipping method. Bio-protocol 7:19-26.

Khaing, E.E., Z.A.M. Ahmad, M. Wong, W.M. Yun and M.R. Ismail. 2015. Effect of silicon and spacing on rice sheath blight disease severity and yield. Int. J. Enhanced Res. Sci. Technol. Engineer. 4:7-11.

Khan, A.J., F.F. Jamil and M.A. Gill. 2000. Screening of rice varieties/lines against bakanae and bacterial leaf blight (BLB). Pak. J. Phytopathol. 12:6-11.

Khan, S.M., N. Javed, S. M. Khan and M. A. Gill. 2002. Screening of rice germplasm against blast disease caused by *Pyricularia oryzae* cav. National Conference of Plant Pathology, NARC, Islamabad, Pakistan; pp.86-89.

Kumar, K.V.K., M.S. Reddy, J.W. Kloepper, K.S. Lawrence, D.E. Groth and M.E. Miller. 2009. Sheath blight diseases of rice (*Oryza sativa* L.): An overview. Biosci. Biotechnol. Res. Asia 6:465-480.

Lore, J.S., Y. Vikal, M.S. Hunjan, R.K. Goel, T.S. Bharaj and G.L. Raina. 2011. Genotypic and pathotypic diversity of *Xanthomonas oryzae* pv. *oryzae*, the cause of bacterial blight of rice in Punjab State of India. J. Phytopathol. Vol:1-9.

Lu, K.Y. and M.L. Cai. 2000. Characteristics of growth and development and high yield cultivation technology in rice. J. Huazhong Agric. Univ. 19:91-94.

Mondal, M.M.A., A.B. Puteh, M.R. Ismail and M.Y. Rafii. 2013. Optimizing plant spacing for modern rice varieties. Int. J. Agric. Biol. 15:175-178.

Myint, S.S., H.K. Nyut, H.K. Ko and M.M. Thein. 2007. Study on the effect of different urea fertilizer rates and plant populations on the severity of bacterial blight of rice. J. Agric. Devel. Tropics Subtropics 108:161-167.

Nino-Liu, D.O., P.C. Ronald and A.J. Bogdanove. 2006. *Xanthomonas oryzae* pathovars: Model pathogens of a model crop. Mol. Plant Pathol. 7:303-324.

Oad, F.C., B.K. Solangi, M.A. Samo, A.A. Lakho, Z.U. Hasan and N.L. Oad. 2001. Growth, yield and relationship of rapeseed under different row spacing. Int. J. Agric. Biol. 3:475-476.

Regan, K. L., K.H.M. Siddique and D. Martin. 2003. Response of Kabuli chickpea (*Cicer arietinum* L.) to sowing rate in Mediterranean-type environments of south-western Australia. Aust. J. Exp. Agric. 43:87–97.

Sah, D.N. and J.M. Bonman. 2008. Effects of seedbed management on blast development in susceptible and partially resistant rice cultivars. J. Phytopathol. 136:73-81.

Savary, S., N.P. Castilla, F.A. Elazegui and P.S. Teng. 2005. Multiple effects of two drivers of agricultural change, labor shortage and water scarcity, on rice pest profiles in tropical Asia. Field Crops Res. 91:263-271.

Soriano, I.R. and G. Reversat. 2003. Management of *Meloidogynae graminocola* and yield of upland rice in South-Luzon, Philippines. Nematology 5:879-884.

Steel, R., J. Torrie and D. Dickey. 1997. Principles and Procedures of Statistics: A biometrical approach, 3rd Ed. McGraw Hill Book Co, New York.

Willocquet, L., L. Fernandezand and S. Savary. 2000. Effect of various crop establishment methods practiced by Asian farmers on epidemics of rice sheath blight caused by *Rhizoctonia solani*. Plant Pathol. 49:346-354.

Wu, W., L. Nie, F. Shah, Y. Liao, K. Cui, D. Jiang and J. Huang. 2014. Influence of canopy structure on sheath blight epidemics in rice. Plant Pathol. 63:98-108.

Yang, X.T., X.Q. Lin, X.H. Wang and S.Z. Luo. 2008. Effects of different transplanting patterns on grain yield and disease resistance of super hybrid rice. Acta. Agric. Zhejiangensi 20:6-9.

Zafar, Z.U., H.R. Athar and M. Ashraf. 2010. Responses of two cotton (*Gossypium hirsutum*) cultivars differing in resistance to leaf curl virus disease to nitrogen nutrition. Pak. J. Bot. 42:2085-2094.

Zhang, F. and J. Xie. 2014. Genes and QTLs resistant to biotic and abiotic stresses from wild rice and their applications in cultivar improvements. Rice-Germplasm, Genetics and Improvement. pp. 9-78.

Zhong, X., S. Peng, R.J. Buresh, N. Huang and H. Zheng. 2006. Some canopy indices influencing sheath blight development in hybrid rice. Chinese J. Rice Sci. 20:535-542.