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# Sowing Dates Influence Incidence of Bacterial Leaf Streak and Rice Yield under Irrigated Production Systems in Burkina Faso



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## Abstract

Bacterial leaf streak (BLS) caused by *Xanthomonas oryzae* pv. *oryzicola* (*Xoc*) is a disease that is prevalent in the main rice-growing sites of Burkina Faso. It causes foliar incidences of up to 100% on some crop varieties and is variable from season to season. Control methods include the use of resistant varieties, integrated pest management and good cultural practices, including sowing dates. Indeed, data on the influence of sowing dates on the incidence of BLS are not well known, especially under the rice cultivation conditions in Burkina Faso. In order to identify sowing dates that would reduce BLS incidence on irrigated plains, we set up a trial in the Kou Valley and Di, using a split-plot design with three rice varieties FKR19, FKR62N and TS2, with susceptibility contrasting levels, at three different date of transplantation. The results show that among the three evaluation dates (June 1st, July 1st and August 1st), the sowing in June is the best because it avoids a high incidence of BLS and allow to obtains a better average yield of the three varieties with 8.10 t/ha and 7 t/ha respectively in the both sites. At June sowing date, infection is less severe for the two susceptible varieties FKR62N and TS2, ranging from 0.33 to 1.93 at Kou Valley compared to 8.06 to 10.16 at Di. However, when sown in August, BLS incidence was higher with a yield reduction of at least 3t/ha compared to June sowing. Therefore, the early planting dates can be recommended for effective control of BLS under irrigated rice growing conditions in Burkina Faso.

## Keywords

*Oryza sativa*, Bacterial leaf streak, *Xanthomonas oryzae* pv. *oryzicola,* Sowing date, Yield

## Introduction

In Burkina Faso, population growth and changing dietary habits have increased the need for rice, especially in urban areas. With urbanization, consumption has increased from 4.2 to 21 kg per capita per year (up to 50 kg in cities) [1]. Since 2008, in response to the food crisis and to compensate for the low level of rice production, the government has strengthened its support measures for production by subsidising seeds and fertilisers. This led to a significant increase in production, which increased from 100,000 to 300,000 tonnes between 2007 and 2012 [2].

Despite this significant production, it does not cover the country's needs, the rest being provided by imports, thus causing a significant outflow of currencies of more than 40 billion CFA francs [3]. Indeed, rice production is subject to numerous abiotic, biotic and socio-economic constraints. Several diseases caused by viral, bacterial and fungal pathogens are part of the biotic constraints and constitute a brake on the development of rice cultivation in Burkina Faso [4]. Among bacterial disease, Bacterial Leaf Streak (BLS) caused by *Xanthomonas oryzae* pv. *oryzicola* (*Xoc*) is present in the main rice-growing sites of Burkina Faso including Bagre and Itenga in the Centre-East region, Bama and Banzon in the Hauts-Bassins, Niassan and Di in the Boucle du Mouhoun, Karfiguela and Douna in the Cascades [5,6]. It should be noted

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that BLS was first described in the Philippines in 1918 [7]. It occurs in several other countries in Asia, Africa, and Oceania [2,8-15]. BLS may affect entire fields and cause yield losses up to 32% [16-18]. BLS is included in the quarantine lists of most rice-growing countries.

Although BLS occurs on most rice growing sites in Burkina Faso, often with high leaf incidences of up to 100% in some plots, its effect on yield has not been evaluated. In addition, depending on the season, we observed variability in incidence within and between sites.

The control methods against BLS are the use of resistant varieties. Zhao [19] reported that a resistance gene against *Xoc* had yet to be characterized in cultivated rice. However, to control BLS in Asia, a dominant maize gene, *Rxo1*, has been isolated and characterized. It confers resistance in maize to *Xoc* and it also prevents the development of *Xoc* when it is expressed as a transgene in rice [20]. Recently, a recessive resistance gene called *bls1* was localized on chromosome 6 of *Oryza rufipogon* [21]. In addition, Triplette [22] were able to determine that the resistance of the Carolina Gold rice variety is conferred by a single dominant locus, *Xo1*, located on a fragment of DNA of 1.09 Mbp on chromosome 4.

Furthermore, the sowing date has an effect on the disease control. Landa [23], Coelho [24], respectively, showed that sowing date reduces the incidence of Fusarium wilt of chickpea and wheat blast disease. In the absence of appropriate means of control against BLS, it is imperative to identify cultural practices, including sowing dates, that will avoid peaks of the disease and thus reduce its incidence.

The aims of this study are to (i) assess the effect of three different sowing dates on the development of BLS, (ii) assess the effect of BLS on the yield of cultivated varieties in order to propose sowing dates and varieties that would reduce the adverse effects of BLS.

## Materials and Methods

### Study site

The tests were carried out at rice-growing sites known for their previous infestation with BLS disease reported by [5,25], which are the irrigated plains of the Kou valley and the Di plains.

The Kou valley plain is located 30 km from Bobo-Dioulasso in the rural municipality of Bama at an altitude of 300 m above sea level between longitude 04°22'W and latitude 11°22'N. It extends over 1,200 ha with a total water control [26]. The climate is typical of southern Sudan, with annual rainfall ranging from 900 to 1,000 mm.

The Di irrigated plain is located in the northwest of Burkina Faso at 326 km from Bobo-Dioulasso. It covers an area of 2,240 ha with total water control. The area lies at an altitude of 277 m above sea level between longitude 3°20'W and latitude 13°18'N. The climate is typical of northern Sudan, with annual rainfall ranging from 600 to 900 mm.

### Plant material

Three rice varieties from INERA germplasm collection, were tested. Their phenotypes against *Xoc* strains were previously evaluated by [27] under artificial inoculation conditions. Their choice is justified by their adoption by producers and consumers in Burkina Faso (Table 1). Source: [28,27].

**Table 1:** Varieties tested in this study.

| | Growing system | Semi-maturity Cycle | Potential yield (t/ha) | Phenotype in artificial inoculation |
|---|---|---|---|---|
| **FKR19** | Lowland/ irriguated | 95 | 6-7 | Resistant |
| **FKR62N** | | 118 | 6-7 | Susceptible |
| **TS2** | | 120 | 6,5-7 | Susceptible |

Source: [28, 27].

### Experimental design

Three tests were set up in the Kou valley and the Di plains respectively at one-month intervals starting June 1, 2019 and 2020 in one farmer's field per site where BLS infection was observed during the wet seasons in 2017 and 2018. The experimental design was a Fisher block randomized to three replicates separated from each other by a distance of 1 meter. The main factor that was assessed was the varieties and the second factor was the disease incidence. Each elementary plot had an area of 4 $m^2$, separated from each other by a distance of 0.5 meters. The total area of the experimental design was 36 $m^2$.

The nurseries were prepared near the plot to be transplanted on June 1$^{st}$, July 1$^{st}$ and August 1$^{st}$, of each year. The 15-day-old rice plants were transplanted at a rate of one sprig per stake. The spacing was 20 cm between the rows and 20 cm between the plants. Transplanting was done on June 15 for the first sowing date, July 15 for the second date and August 15 for the third date. Mineral fertilization was done at the rate of 200 Kg of NPK/ha and 150 Kg of urea/ha. NPK application was done at 21 days after sowing (DAS). Urea was applied in two steps, one half at the beginning of tillering (15 days after transplanting, DAR) and the other half at panicle initiation (55-65 DAR). The presence of water in the plot was controlled by the irrigation system. No phytosanitary treatments were carried out during the entire crop cycle. However, manual weeding was done when necessary.

### Data collection

Several parameters were collected at each site to assess the resistance or susceptibility level of the both rice varieties tested.

The disease incidence was determined for each plant from the 30th DAT, then every 14 days until maturity. It was obtained by counting the number of infected plants per genotype in each elementary plot and calculated by the following formula: $I = \sum_{i=1}^{n}\left(\frac{xi}{X}*100\right)$ ; with n = the number of repetitions, xi = the number of diseased plants per elementary plot, and X = the total number of rice plants per elementary plot.

The foliar incidence was evaluated for 10 plants chosen at random on the two diagonals in each elementary plot. It was calculated by counting the number of infected leaves out of the total number of leaves according to the following formula: $IF = \sum_{i=1}^{n}\left(\frac{xi + ....... + xi + 1}{X}\right)*100$; with n = the number of repetitions, xi = the number of diseased leaves/plant, and X = the total number of leaves. The phenotype of each variety was determined by using [29].

The disease severity (S) was evaluated on the 10 plants chosen to estimate the disease incidence. Severity (S) expressed as a percentage of the total tissue area, was calculated by using the scale of [30] as follows: S = [(n1x1) + (n3x3) + n5x5) + n7x7) + n9x9)] x100 / (n1 + n3 + n5 + n7 + n9) x9; where n1 to n9 are the numbers of leaves denoted from 1 to 9.

(iv) Paddy yield was estimated from the three center lines of each elementary plot, comprising 15 plants that were harvested at maturity. The panicles were sun-dried and the seeds weighed. Yield losses (%) were estimated by comparing the yields obtained in July and August with that of June, which was considered optimal.

## Data analysis

Microsoft Excel 2010 software was used for data entry and to calculate the BLS incidence and severity, and paddy yield. Statistica 7.1 software was used for ANOVA tests and to establish the correlation between severity and yield. The comparison of averages was done by the Newman Keuls test at the 5% level.

# Results

## Interaction between varieties, sites and seasons

Analyses of variance of the interaction effect between varieties, sites and seasons showed significant differences for severity. The variety FKR19 did not show any severity across sites and seasons. The analysis shows that severity was higher in 2020 at all sites with respectively 40.61% and 27.12% at Di and Kou Valley. Also, the Di site recorded more severity in all wet seasons with 27.51 in 2019 and 40.61 in 2020. The variety FKR62N recorded more severity in all seasons in the both sites (Table 2).

**Table 2:** Joint analysis of variance of interactions between varieties, sites, seasons and severity.

| Varieties | Year | Sites | Severity |
|---|---|---|---|
| **FKR19** | 2019 | Kou Valley | 0a |
| | 2020 | Di | 0a |
| | 2020 | Kou Valley | 0a |
| | 2019 | Di | 0a |
| **TS2** | 2019 | Kou Valley | 12,7ab |
| | 2020 | Kou Valley | 16,01abc |
| | 2019 | Di | 28,03bc |
| | 2020 | Di | 32,21bc |
| **FKR62N** | 2019 | Kou Valley | 22,01abc |
| | 2020 | Kou Valley | 27,12bc |
| | 2019 | Di | 27,51bc |
| | 2020 | Di | 40,61c |
| **P value** | | | **0,014** |

The values followed by the same letter are not significantly different at the 5% threshold according to the Newman Keuls test.

## Plant incidence

Incidence levels of rice varieties at the three sowing dates (June, July and August) varied significantly at the same date and between the sowing dates (Table 3). The lowest incidence values were recorded at the June sowing date for susceptible varieties FKR62N and TS2 on the both sites. However, they were more sensitive at Di than Kou valley. Their sensitivity increases when sown in July and August respectively. Meanwhile, the variety FKR19 remains immune when sown in June, and resistant for July and August sowing with an incidence of 2.16 and 4.16 respectively at Kou valley and Di.

**Table 3:** Average incidence levels per plant of each variety.

| Varieties | Sowing date | Kou Valley | Di |
|---|---|---|---|
| | | Incidence (%) | Incidence (%) |
| **FKR19** | June[1st] | 0a | 0a |
| | July[1st] | 0a | 8,79a |
| | August[1st] | 2,16a | 4,16a |
| **FKR62N** | June[1st] | 6,41a | 56,63a |
| | July[1st] | 82b | 100b |
| | August[1st] | 100c | 98,86b |
| **TS2** | June[1st] | 10,32a | 62,67a |
| | July[1st] | 51,5b | 100c |
| | August[1st] | 89,41c | 87,84b |

The values followed by the same letter on a line and according to the year are not significantly different at the 5% threshold according to the Newman Keuls test. The separations are made by date for the same variety

## Foliar incidence

The foliar incidence is strongly correlated to the incidence per plant of each variety tested. Table 4 showed that the foliar incidence varied significantly for the same variety between sowing dates independently of the sites and years. The susceptible varieties FKR62N and TS2 may recorded foliar incidence of more than 50% or even 100% from the July and August sowings. As for FKR19 variety, NO foliar incidence was recorded regardless of site and crop year.

The values followed by the same letter for each cultivar on a column and according to the year, are not significantly different at the threshold of 5% according to the Newman Keuls test. Separations are made by date for the same variety

## BLS severity

Disease severity recorded on each variety was proportional to the foliar incidence. It varied according sowing dates and cropping year (Table 5). The variety FKR19 did not recorded any severity rating, regardless of sowing date, site and year. However, with the varieties FKR62N and TS2, low disease severity was recorded when sown in June. The August sowings were the most favourable for disease expression on these two varieties.

**Table 4:** Foliar incidence level (%) of BLS on rice varieties at the three sowing dates.

| Varieties | SD | Valley Kou | | Di | |
|---|---|---|---|---|---|
| | | 2019 | 2020 | 2019 | 2020 |
| | | FI (%) | | | |
| **FKR19** | June1st | 0a | 0a | 0a | 0a |
| | July1st | 0a | 0a | 0a | 1.66a |
| | August1st | 0a | 0a | 0a | 0.27a |
| **FKR62N** | June1st | 0a | 9a | 7.66a | 42.93a |
| | July1st | 54.37b | 64b | 86.33b | 100b |
| | August1st | 81.66c | 85.33b | 78.33b | 91.66b |
| **TS2** | June1st | 5.66a | 6a | 30.66a | 27.04a |
| | July1st | 26ab | 39.33b | 100c | 100c |
| | August1st | 67.66b | 69.66c | 62.33b | 77.53b |

**FI:** Foliar Incidence; **SD**: Sowing Date

**Table 5:** Severity (%) of BLS on rice varieties at the three sowing dates.

| Varieties | SD | Valley Kou | | Di | |
|---|---|---|---|---|---|
| | | 2019 | 2020 | 2019 | 2020 |
| | | Severity (%) | | | |
| | June1st | 0a | 0a | 0a | 0a |
| **FKR19** | July1st | 0a | 0a | 0a | 0a |
| | August1st | 0a | 0a | 0a | 0a |
| | June1st | 0a | 0.66a | 0.83a | 15.27a |
| **FKR62N** | July1st | 18.01b | 24b | 57.02c | 62.66c |
| | August1st | 48.03c | 56.7c | 24.68b | 43.9b |
| | June1st | 2.83a | 1.03a | 12.52a | 7.8a |
| **TS2** | July1st | 4.6a | 9.66b | 52.09b | 55.43c |
| | August1st | 30.66b | 37.33b | 19.47a | 33.4b |

**SD**: Sowing Date

**Table 6:** Average yields (%) and losses (T ha-1) per rice varieties at the three sowing dates in the Kou Valley.

| Varieties | Valley Kou | | | | | Di | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sowing date | 2019 | | 2020 | | 2019 | | 2020 | |
| | | GY | YL | GY | YL | GY | YL | GY | YL |
| | June1st | 8b | | 7.9b | | 6.8b | | 7.75b | |
| **FKR19** | July1st | 6.67ab | 16,62 | 7.25b | 8,22 | 5.75ab | 15,44 | 6.25ab | 19,35 |
| | August1st | 3.9a | 51,25 | 4a | 49,36 | 3.9a | 42,64 | 3.75a | 51,61 |
| | June1st | 8.15b | | 8.07c | | 6.95b | | 6.95b | |
| **FKR62N** | July1st | 5.32a | 34,48 | 5.25b | 34,94 | 3.5a | 49,64 | 3.075a | 55,75 |
| | August1st | 4.32a | 46,79 | 3.825a | 52,66 | 3.4a | 51,07 | 3.32a | 52,23 |
| | June1st | 8b | | 8.5b | | 6.62b | | 6.9b | |
| **TS2** | July1st | 4.57a | 42,87 | 5.07a | 40,35 | 3.4a | 48,64 | 3.325a | 51,81 |
| | August1st | 4.12a | 48,5 | 4.25a | 50 | 3.15a | 52,41 | 3.825a | 44,63 |

Yield losses (%) were estimated by comparing the yields obtained in July and August with that of June, which was considered optimal. **GY**: Grain Yield; **YL**: Yield Losse.

The values followed by the same letter for each cultivar on a column and according to the year, are not significantly different at the threshold of 5% according to the Newman Keuls test. Separations are made by date for the same variety.

## Effect of sowing dates on the average yield of rice varieties

The comparative analysis of yields between sowing dates shows that for the same variety, the average yields obtained are significatively different ($p < 0.05$) according the cropping year and site (Table 6). The high yields were obtained for all varieties when they sow at June. In contrast, the yield decreases when the sowing were achieved in July and august. As considering optimal yield obtained in June, we recorded yields losses ranged from 8.22 to 55.77% with FKR62N and TS2 varieties. Moreover, the best yields are obtained in the Kou Valley whatever the variety.

The values followed by the same letter for each cultivar on a column and according to the year, are not significantly different at the threshold of 5% according to the Newman Keuls test. Separations are made by date for the same variety.

### Correlation between BLS severity and yield

Correlation analysis between disease severity and yield showed a very highly significant negative overall correlation regardless of year and study site. Yields of susceptible varieties, TS2 and FKR62N are less affected when sown in June and July ($-0.23 \leq r \leq -0.02$; $0.65 \leq p \leq 0.8$) especially at the Kou Valley site. However, at Di, yields are affected by bacterial leaf streak when sown at the same dates.

## Discussion

### Disease incidence and severity

The results showed that the variety FKR19 had a very low level of incidence regardless of site and season. However, this variety was resistant at different developmental stages under artificial inoculation conditions [27]. The infection of FKR19 variety at a late stage in the field, but with a very low incidence confirms its resistance/tolerance compared to the other two varieties. Indeed, in the environment, there is significant diversity within the population of a pathogen. Therefore, the infection would be due to one or more strains of *X. oryzae* pv. *oryzicola* of different genetic group than the one tested by [27] under semi-controlled conditions. In addition, several environmental factors favourable to pathogen infection such as temperature, humidity and rainfall were optimal during the trial. Similar results were obtained by [31] and [32] on the wheat tested against blast disease at different sowing dates.

In view of the level of resistance of FRK19 variety, it could serve as a source of resistance gene(s) for the improvement of susceptible varieties such as FKR62N and TS2.

Our results showed that highest severity and foliar incidence were recorded in susceptible varieties when sown July and August according the sites and cropping dates, with a high disease prevalence in Di site. Indeed, in the Kou Valley and Di perimeters, the double rice production season is achieved even if the area sown in the dry season is less important. In addition, apart from the main host, which is rice for Xoc, weed hosts are permanently present in the rice plains [25]. Thus, the sources of inoculum being important and diverse, the months of July and August, characterized by good rainfall and high relative humidity, could induced severe infections observed on the susceptible varieties. These results are similar to those of [33] who indicated that with later transplanting is later, the BLS prevalence is higher.

### Effect of sowing dates on yield

The results show an overall negative correlation between the severity and yield.

The results show an overall negative correlation between disease severity and yield. Indeed, the high BLS severity induces more than 50% yield losses on FKR62N and TS2 varieties. These results are consistent with those [11] showed that Xoc could cause yield losses of up to 50% under severe infection. In addition, climatic factors including rainfall, temperature and humidity and soils properties can influence negatively the yields [11,34-37].

Indeed, with the late sowing (August 1st), the rice grain formation phase coincide with the cold period that started in October. Consequently, this environmental conditions induce a reduction in the number of grains per panicle that decrease yield [38,39].

Between the two sites, we obtained different yield for the same variety of up to 700 kg, with the best yields obtained in the Kou Valley. This wide variability in varietal performance could be related to the soils properties on the both sites addition to BLS prevalence.

BLS is high prevalent at Di site related to the geographical location of the plain and the cultivation practices of the producers [25]. Indeed, the Di plain borders the Sourou river whose banks are populated by *Oryza longistaminata*, a species of wild rice which, according to [25], the main source of spread of BLS on cultivated varieties. It should be noted, however, that the stand of *O. longistaminata* at Kou Valley is less important than that at Di, certainly related to the duration of the exploitation of the plain and also to the level of knowledge of the producers in integrated weed management.

We observed that on Di site, *O. longistaminata* is conserved by farmers at the edge of plots to mark their boundaries. This wild species is also found in wastewater drainage canals serving as intermediate hosts for *Xoc* from one season to another.

## Conclusion

The objective of this study was to identify the sowing dates that would reduce the incidence of BLS on the irrigated plains of the Kou and Di valleys and obtain the best yield of the cultivated varieties. Our results show that the sowing date of June 1st is the best as it avoids a high incidence of BLS and obtains a better yield of three tested varieties. However, regardless of variety, there was more than 50% yield reduction when sown later.

Interestingly, FKR19 variety used as a resistant control confirmed its resistance/tolerance to BLS on both rice plains regardless of sowing date and could be used to improve susceptible varieties that are FKR62N and TS2. In view of these results, we can recommend to producers that they plant their crops in June in accordance with the agricultural calendar.

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