Evaluation of maize genotypes against post flowering stalk rot under terai region of Nepal

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ABSTRACT

The inadequate source of resistance materials in maize against major biotic stresses is one of the main reasons for considerable loss of grain yield in Nepal. Post flowering stalk rot disease caused by Fusarium moniliforme is a serious disease that exposes high incidence at grain filling stage of maize in terai region of Nepal during summer season. This study was done to evaluate level of resistance, or tolerance in selected genotypes against the post flowering stalk rot disease of maize. Accordingly, thirty maize genotypes were tested for maize stalk rot resistance during summer season of 2016 and 2017 at National Maize Research Program, Rampur (NMRP), Chitwan. The experiment was done under natural epiphytotic condition at hot spot of the disease by using Randomized Complete Block design with 2 replications for each treatment. The package of practices was followed as per national recommendation. The summer season of 2016 and 2017 were affable for post flowering stalk rot of maize at NMRP, Rampur. Out of 30 genotypes, most of the tested entries showed susceptible reaction during both the years; however, RML-95/RML-96, Across-9942/Across-9944, ZM-401, Rampur 34, RamS03F08 and TLBRS07F16 showed resistant reaction against the disease and might be useful for the development of post flowering stalk resistant maize varieties for terai region of Nepal.

Keywords: Fusarium moniliforme, resistance, post flowering

INTRODUCTION

Stalk rot complex of maize is recognized as a severe problem in the tropical and sub-tropical maize growing areas of Nepal. This disease slowly becomes a serious threat in most of the terai and mid hill-low lying maize growing areas of Nepal (Subedi et al., 2016). Usually post flowering maize stalk rot is prominent than pre-flowering to reduce maize yield (Batsa & Neupane, 1982). The pre-flowering type of stalk rot includes pythium stalk rot (Pythium aphanidermatum) and bacterial stalk rot (Erwinia chrysanthemi pv. Zeae) whereas others,
such as *Fusarium* wilt (*Fusarium moniliforme* J. Sheld), late wilt (*Cephalosporium maydis*), black bundle disease and charcoal rot (*Macrophomina phaseolina*), appear in the post-flowering phase (Subedi, 2015). Stalk rot has been distributed throughout the country, but it is most prevalent in the hot and humid areas such as Dang, Chitwan, Nawalparasi, and Surkhet (NMRP, 2015). However, *Pythium* stalk rot is found to be common in the mountains and the valleys in Nepal (Diwakar & Payak, 1975). From global point of view, an estimated yield loss of 9-10% has been reported due to stalk rot complex that varied 4% in northern Europe and 14 % in South Asia and West Africa (Oerke, 2005). It has been estimated that post flowering stalk rot of maize in Nepal can cause up to 80 % yield loss along with other fungal diseases, especially in the terai area (Subedi et al., 2016). Indeed, *Fusarium* Stalk Rot is associated with stalk rots and causes comparatively more damage in tropical compared to temperate countries (Christensen & Wilcoxson, 1966). The pathogen causes a permanent wilting, where leaves become flabby, basal stalk tissues turns to pinkish to purple tinge colorations (Agrios, 2005). There is no external visible symptom of the fungus. Although several works have been done to cope up with other maize diseases (Manandhar, 1997) but research activities were less in the maize stalk rot complex management in Nepal. In this sense, an instant effort is needed to manage stalk rot aiming to support tropical and subtropical maize growers to help manage this disease. Fungicidal control of *Fusarium* stalk rot is not successful due to its soil-borne mechanism of infection. Alternatively, the exploration and use of resistance gene(s) to enhance the tolerance of maize to stalk rot is a cost-effective and environmentally sustainable approach to its management. The objective of this research was to evaluate the maize genotypes against post flowering stalk rot disease considering grain yield management and to increase the maize productivity.

**MATERIALS AND METHODS**

Thirty maize genotypes were screened for maize stalk rot resistance during summer season of 2016 and 2017 at National Maize Research Program (NMRP), Rampur, Chitwan. The latitude, longitude and altitude of the experimental site are 27° 40’N, 84° 19’ E, and 228 masl respectively. The experiment was done at natural epiphytotic condition by using Randomized Complete Block design with an arrangement of each treatment with 2 replications. The plot size was 5m long with 75 cm row to row spacing, and each genotype was sown in two rows. All agronomic practices were followed as per standard of National Maize Research Program, Rampur (NMRP, 2015). Farm yard manure (FYM) @15 t/ha in combination with chemical fertilizer @120:60:40 N: P: K kg/ha was applied. Di-ammonium phosphate (DAP) and Murate of potash (MoP) were applied as basal whereas urea was top dressed in three splits. Early plant stand, 50% days to anthesis and silking, plant height (cm), ear height (cm) and final plant stand (number) were recorded (CIMMYT, 1985). The disease severity were recorded from 10 randomly tagged plants/plot on the basis of 1-9 scoring scale (ICAR, 2012), thrice at an interval of 10 days. The area under disease progress curve (AUDPC) was computed using midpoint rule method (Campbell & Madden, 1990). The grain yield (kg/ha) and Thousand kernel weight (g) were recorded. Grain yield (t/ha) at 15% moisture content was calculated using fresh ear weight with the help of the formula adopted by Shrestha et al. (2019) and Shrestha et al. (2018). All data were analyzed statistically using Microsoft Excel and MSTAT-C computer package program.
RESULTS AND DISCUSSION

The maize growing summer season of 2016 was friendly for post flowering stalk rot development. The early plant stand, disease severity, final plant stand, grain yield, and thousand seed weight were significantly (p<0.05) varied among the tested maize genotypes during summer of 2016 at Rampur, Chitwan. Out of 30 genotypes, the lower AUDPC value

Table 1. Screening of maize genotypes against post flowering stalk rot disease at Rampur, Chitwan during summer of 2016

| Genotypes                  | EPS | Disease Severity (1-9) | AUDPC 60 DAS | AUDPC 70 DAS | AUDPC 80 DAS | FPS | GY (kg/ha) | TKW (g) |
|----------------------------|-----|------------------------|--------------|--------------|--------------|-----|------------|---------|
| RML-95/RML-96              | 35  | 1.53                   | 4.53         | 3.73         | 2.73         | 63  | 2127       | 315     |
| Across-9942/Across-9944    | 37  | 1.78                   | 3.12         | 1.96         | 2.03         | 56  | 1987       | 548     |
| Poshilo Makai 1            | 30  | 3.15                   | 1.50         | 1.00         | 1.00         | 82  | 1444       | 283     |
| S99TLQY-B                  | 37  | 3.15                   | 1.50         | 1.00         | 1.00         | 81  | 1329       | 285     |
| S99TLQY-HG-AB              | 40  | 3.98                   | 2.88         | 2.22         | 1.44         | 99  | 835        | 315     |
| BGBYPOP                    | 35  | 2.80                   | 1.33         | 1.00         | 1.00         | 75  | 1540       | 205     |
| R pop-3                    | 31  | 3.28                   | 2.88         | 2.33         | 1.88         | 85  | 1232       | 335     |
| R pop-4                    | 37  | 2.60                   | 2.13         | 1.50         | 1.00         | 69  | 1643       | 268     |
| Rampur Hybrid-4            | 35  | 2.63                   | 2.13         | 1.50         | 1.00         | 70  | 1626       | 350     |
| Rampur Hybrid-6            | 34  | 2.88                   | 2.77         | 2.22         | 1.44         | 77  | 1509       | 220     |
| Rampur Composite           | 40  | 4.20                   | 3.77         | 3.22         | 2.22         | 103 | 864        | 275     |
| RAMS03F08                  | 34  | 2.20                   | 1.77         | 1.22         | 1.00         | 62  | 1949       | 273     |
| ZM-401                     | 33  | 2.69                   | 2.13         | 1.50         | 1.00         | 72  | 1670       | 343     |
| ZM-627                     | 42  | 5.08                   | 4.50         | 3.50         | 2.50         | 115 | 505        | 388     |
| 05 SADV1                   | 34  | 3.80                   | 3.22         | 2.50         | 1.50         | 94  | 1034       | 260     |
| 07 SADV1                   | 35  | 3.50                   | 2.77         | 2.22         | 1.44         | 89  | 1124       | 335     |
| Rampur 21                  | 38  | 5.35                   | 4.88         | 4.33         | 3.33         | 125 | 505        | 363     |
| Rampur 24                  | 34  | 3.70                   | 3.22         | 2.50         | 1.50         | 93  | 1033       | 305     |
| Rampur 27                  | 36  | 2.43                   | 1.95         | 1.50         | 1.00         | 67  | 1731       | 358     |
| Rampur 32                  | 28  | 2.80                   | 2.33         | 1.88         | 1.33         | 74  | 1660       | 353     |
| Rampur 33                  | 33  | 3.60                   | 3.13         | 2.66         | 1.66         | 91  | 1935       | 368     |
| Rampur 34                  | 33  | 1.98                   | 1.50         | 1.00         | 1.00         | 60  | 1935       | 368     |
| Rampur 36                  | 37  | 3.08                   | 2.50         | 2.00         | 1.50         | 81  | 1363       | 275     |
| TLBRS07F16                 | 38  | 2.40                   | 1.95         | 1.50         | 1.00         | 66  | 1762       | 415     |
| Across 9331 RE             | 36  | 3.40                   | 2.90         | 2.40         | 1.90         | 87  | 1181       | 365     |
| Arun-2                     | 30  | 3.73                   | 3.23         | 2.73         | 2.23         | 95  | 1033       | 353     |
| BLBRS07F10                 | 37  | 2.93                   | 2.43         | 1.93         | 1.43         | 78  | 1540       | 318     |
| TLBRS07F14                 | 36  | 3.63                   | 3.13         | 2.63         | 2.13         | 92  | 1076       | 358     |
| Arun-4                     | 40  | 2.84                   | 2.38         | 1.88         | 1.38         | 75  | 1545       | 315     |
| Farmer’s Local (SC)        | 41  | 5.20                   | 4.77         | 4.27         | 3.77         | 119 | 422        | 315     |
| Grand mean                | 35.43 | 3.21            | 2.86         | 2.43         | 2.03         | 83  | 1938       | 332.62  |
| F-test                     | **  | **                 | **           | **           | **           | **  | **        | 317.33  |
| CV%                        | 3.98 | 1.27              | 1.34         | 1.11         | 1.07         | 4.50| 2.39       | 2.47    |

*Means of 2 replications. EPS- Early Plant Stand, AUDPC- Area under Disease Progress Curve, FPS- Final Plant Stand, GY- Grain Yield (kilogram/hectare), TKW (g)- Thousand kernel Weight (g), DAS- Days after Sowing, SC- Susceptible Check, ** highly significant (p<0.001)
Table 2. Evaluation of common agronomic traits of maize genotypes in post flowering stalk rot screening nursery at Rampur, Chitwan during summer of 2016

| Genotypes            | 50% Plant height (cm) | 50% Ear height (cm) |
|----------------------|-----------------------|---------------------|
| RML-95/RML-96        | 52                    | 180                 |
| Across-9942/Across-9944 | 50            | 180                  |
| Poshilo Makai 1      | 52                    | 178                 |
| S99TLYQ-B            | 52                    | 156                 |
| S99TLYQ-HG-AB        | 52                    | 171                 |
| GBGYPOP              | 52                    | 165                 |
| R pop-3              | 50                    | 147                 |
| R pop-4              | 49                    | 176                 |
| Rampur Hybrid-4      | 55                    | 149                 |
| Rampur Hybrid-6      | 55                    | 160                 |
| Rampur Composite     | 57                    | 174                 |
| RAMS03F08            | 51                    | 185                 |
| ZM-401               | 49                    | 160                 |
| ZM-627               | 53                    | 150                 |
| 05 SADVI             | 54                    | 150                 |
| 07 SADVI             | 54                    | 166                 |
| Rampur 21            | 52                    | 184                 |
| Rampur 24            | 55                    | 136                 |
| Rampur 27            | 57                    | 161                 |
| Rampur 32            | 55                    | 173                 |
| Rampur 33            | 54                    | 140                 |
| Rampur 34            | 55                    | 154                 |
| Rampur 36            | 55                    | 164                 |
| TLBRS07F16           | 58                    | 173                 |
| Across 9331 RE       | 50                    | 150                 |
| Arun-2               | 54                    | 171                 |
| BLBRS07F10           | 51                    | 174                 |
| TLBRS07F14           | 57                    | 157                 |
| Arun-4               | 47                    | 143                 |
| Farmer’s Local (SC)  | 58                    | 172                 |
| Grand mean           | 52.25                  | 163.15              |

The plant height and ear height were significantly varied among the tested genotypes (Table 2). The 50% anthesis days, 50% silking days, plant height and ear height were also significantly varied among the tested genotypes (Table 2). The results showed that 50%
anthesis days varied from 46 days for Across-9942/Across-9944 to 58 days for TLBRS07F16. Similarly, the 50% silking days varied from 50-61 days. Likewise, the plant height varied from 136 cm for Rampur 24 to 185 cm for RAMS03F08. Similarly, the ear height also varied from 60 cm of Rampur 24 to 100 cm of R pop-4 (Table 2).

**Relationship between grain yield (kg/ha) and AUDPC**

Findings of this study revealed highly significant negative correlation ($r = -0.99$) with the AUDPC value of post flowering maize stalk rot disease to the grain yield during summer maize season (2016). This relationship was drawn among 6 (3 high yielding- RML-95/RML-96, Across-9942/Across-9944, RAMS03F08, and 3 low yielding- ZM 627, Farmers local, and Rampur 21) genotypes (Figure 1). The predicted linear regression line also displayed downward slope i.e. $y = -0.039x+136.5$, with regression coefficient $R^2 = 0.99$, where ‘y’ denoted predicted crop yield of maize genotypes and ‘x’ stood for AUDPC of post flowering stalk rot of maize (Figure 1). The estimated regression line indicated that with the one unit rise in the AUDPC of stalk rot disease (within 1-9 scale), there existed possibilities of yield reduction by 135.96 kg/ha.

![Figure 1. Relationship between crop yield (kg/ha) and AUDPC of maize stalk rot complex in screening experiment at Rampur, Chitwan during 2016](image)

The summer season of 2017 was also favorable for post flowering stalk rot of maize at NMRP, Rampur. Out of 30 genotypes, During 2017 growing year, genotypes having lower AUDPC value were RML-95/RML-96 (73), Across-9942/Across-9944 (78), ZM-401 (81), Rampur-34 (81), RamS03F08 (89) and TLBRS07F16 (89) respectively (Table 3). The high yielding genotypes were RML-95/RML-96 (3883 kg/ha) followed by Across-9942/Across-9944 (3395 kg/ha), and Rampur 34 (3275 kg/ha) respectively (Table 3).
Table 3. Screening of maize genotypes against post flowering stalk rot disease at Rampur, Chitwan during summer of 2017

| Genotypes             | AUDPC  | Grain yield (kg/ha) | TKW (g) |
|-----------------------|--------|---------------------|---------|
| RML-95/RML-96         | 72.50  | 3883                | 300     |
| Across-9942/Across-9944 | 77.75  | 3395                | 270     |
| Poshilo Makai 1       | 104.00 | 1873                | 280     |
| S99TLYQ-B             | 120.00 | 2298                | 310     |
| S99TLYQ-HG-AB         | 122.50 | 1408                | 290     |
| BG BY POP             | 104.00 | 1983                | 275     |
| R pop-3               | 131.50 | 2053                | 355     |
| R pop-4               | 131.50 | 1444                | 275     |
| Rampur Hybrid-4       | 117.50 | 1761                | 300     |
| Rampur Hybrid-6       | 122.50 | 1199                | 210     |
| Rampur Composite      | 110.00 | 1441                | 290     |
| RAMS03 F08            | 88.50  | 3248                | 270     |
| ZM-401                | 81.25  | 2733                | 300     |
| ZM-627                | 136.25 | 341                 | 350     |
| 05 SADVI              | 135.00 | 1691                | 250     |
| 07 SADVI              | 134.00 | 1939                | 315     |
| Rampur 21             | 155.00 | 588                 | 100     |
| Rampur 24             | 151.25 | 1772                | 290     |
| Rampur 27             | 118.75 | 2952                | 285     |
| Rampur 32             | 117.50 | 2717                | 295     |
| Rampur 33             | 94.00  | 1779                | 235     |
| Rampur 34             | 81.25  | 3275                | 350     |
| Rampur 36             | 119.25 | 1976                | 290     |
| TL BRS07F16           | 89.00  | 2954                | 335     |
| Across 9331 RE        | 141.25 | 2005                | 260     |
| Arun-2                | 97.50  | 1721                | 340     |
| BLSBR S07F10          | 107.50 | 2634                | 290     |
| TL BRS07F14           | 94.00  | 1793                | 355     |
| Arun-4                | 104.00 | 2535                | 300     |
| Farmer’s Local (SC)   | 107.00 | 1786                | 335     |
| Grand mean            | 112.20 | 2106                | 290     |
| F-test                | **     | **                  | NS      |
| CV%                   | 2.3    | 1.76                | 19.59   |

† Means of 2 replications. AUDPC - Area under Disease Progress Curve, kg/ha-kilogram/hectare, TKW (g) - Thousand Kernel Weight (gram), SC - Susceptible Check, ** - highly significant (p<0.001)

Maize stalk rot is more prominent in Nepal, India, Indonesia, Pakistan, Philippines, Thailand and Vietnam. This could be observed more commonly if there is a period of drought during, or shortly after pollination (Subedi, 2015). Stalk rot complex include both bacterial (Burlakoti & KC, 2004) and fungal association to cause the significant yield loss in Nepal. Agronomically desirable stalk rot-resistant materials are available in Pakistan, India, Mexico and Zimbabwe, where selections against these diseases have been made (Kulkarni & Anahosur, 2011). The stay green character, in which plants remain green after attaining physiological maturity, has been associated with resistance to certain post-flowering stalk rots (Singh et al., 2012). There is evidence of mammalian toxicity where stalks infected with these pathogens (Agrios, 2005). The maximum disease development occurs within a temperature range of 30-35°C, with a relative humidity of 80-100% (Subedi et al., 2016). Waterlogged, low-lying, or poorly drained field conditions favor a high degree of disease development. Plant age (pre-flowering growth stage) and a large plant population (≥ 60000
per ha) favor a high incidence of disease (Diwakar & Payak, 1980). Resistance to stalk rot disease involves several traits including physiological, morphological and functional characters. Maize stalk strength is determined by both stalk morphology and abiotic stress factor (Singh et al., 2012). The finding of this experiment is in agreement with the finding of Shekhar et al., (2010) as the authors reported that after extensive screening, three resistant lines- PFSR-13-5, JCY2-2-4-1-1-1-1, and JCY3-7-1-2-1-b-1 were identified and also the resistance level of five pools/populations; (PFSR (Y)-C1, PFSR (white), Extra-early (White), P-100, P-300 and P-345) was upgraded to an acceptable level (Shekhar et al., 2010). Stalk rot infectivity depends on environmental factors, the genotype and environment interaction (GxE) and host resistance of maize genotypes to the pathogens (Szoke et al., 2007). Ledencan et al., (2003) marked low disease scoring of hybrids than inbreds and differed significantly in resistance and infection types. Hybrids Ganga Safed-2, Hi-starch, and composites Suwan 1 and Suwan 2, have shown resistance in India (Khokhar et al., 2014). Globally, large numbers of maize germplasm have been tested for stalk rot resistance and some have shown high resistance levels (Ali & Yan, 2012). Studies have shown that resistance to stalk rot is quantitatively inherited and controlled by multiple genes with additive effects (Hooda et al., 2012). From this experiment, it is clear that maize genotypes varied significantly in resistance and infection forms, and the hybrid disease score was typically lower than that of others. This would allow the identification of potential resistance genes for resistance to stalk rot in maize.

CONCLUSION

Throughout the years, maize genotypes RML-95/RML-96, Across-9942/Across-9944, ZM-401, Rampur 34, RamS03F08 and TLBRS07F16 showed resistant reaction against the post flowering stalk rot disease with higher yield at Rampur Chitwan. The genotypes having resistance against post flowering stalk rot would be further evaluated in maize breeding program for the development of stalk rot resistant high yielding maize varieties, thus are critically considered as selected and promising ones.

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Authors’ contributions

Dr. S. Subedi was the principle investigator of this research who prepared and finalized the manuscript. Dr. S. Neupane helped during field research and DR. KB Koirala reviewed the manuscript and helped during draft preparation. Mr. L. Oli helped during data recording and field work.

Conflict of interest

The authors declare that there is no conflict of interest.
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