academicJournals

Vol. 11(29), pp. 2640-2649, 21 July, 2016
DOI: 10.5897/AJAR2016.11154
Article Number: 5CA834659565
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Wheat stem rust disease incidence and severity associated with farming practices in the Central Rift Valley of Kenya

Beatrice Nafula Tenge[1]*, Pascal Peter Okwiri Ojwang[2], Daniel Otaye[2] and Maurice Edwards Oyoo[2]

[1]Kenya Agricultural and Livestock research Organization (KALRO), Njoro, Kenya.
[2]Egerton University, Kenya.

Received 26 April, 2016; Accepted 2 June, 2016

Stem rust (*Puccinia graminis* f.sp.*tritici*) is a major disease of wheat that occurs more in the main wheat growing regions of Kenya. The objective of this study was to assess the incidence and severity of wheat stem rust during the 2015 growing season. A survey was conducted in Mau-Narok, Njoro and Kabatini regions. During the survey work, 149 small scale wheat growers' fields were assessed. The results revealed that stem rust incidence of the three surveyed areas ranged from 11.3 to 77.8% and severity 20 to 60%. The survey confirmed that the incidence and severity were associated with the farming practices such as chemical control, varieties grown, use of certified or uncertified seed and cropping systems. The survey showed that high to moderate incidence and severity levels were found on fields with one or two sprays with a fungicide. The use of fungicide was the major practice by growers for stem rust control reporting Mau-Narok with 43.2%, Kabatini 38.9% and Njoro 17.8%. The varieties grown had a relationship to disease incidence and severity percent levels. The use of uncertified seed by farmers contributed to high disease incidence. About 50.6% growers preferred old varieties mainly Robin and NjoroBWII. About 97.8% of the farmers practiced crop rotation of wheat with legumes. A multi-tactic disease management approach mainly two fungicide sprays per growing season, use at recommended rates, planting of certified seed of resistant varieties and crop rotation of legumes with wheat are required as stem rust effective management strategies.

Key words: Wheat production, farm classifications, disease assessment, survey.

INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the worlds' most productive and important crops in the 21st century (Curtis and Halford, 2014). It is one of the key staple crops for global food security, providing more than 35% of the cereal calorie intake in the developing world, 74% in the developed world and 41% globally from direct consumption (Shiferaw et al., 2013). Due to increased consumption and demand for grain, for food (Curtis and

*Corresponding author. E-mail: beatricetenge@yahoo.com.

Halford, 2014) wheat yields must be increased as this is seen as an important strategy to prevent food shortages (Curtis and Halford, 2014).

Wheat is the second most important cereal staple food after maize in Kenya (USAID, 2010). In Kenya it is grown mostly in the Rift Valley, some areas of upper Central province (Nyandarua, Nyeri) and parts of Meru (Timau) (USAID, 2010). Inspite of the importance of wheat, plant disease is still a major constraint to its production. Plant diseases have been reported to reduce crop yields worldwide, leading to significant crop losses (Khoury and Makkouk, 2010). Stem or black rust, caused by *Puccinia graminis*, has historically caused severe losses to wheat production worldwide (Njau et al., 2009).

In most wheat-growing regions of the world, existing environmental conditions will favour stem rust infection, which at times leads to epidemic buildup (Singh et al., 2011). The situation is worsened by the fact that susceptible wheat varieties are grown over large areas and that a large proportion of current breeding materials are susceptible to stem rust race *Ug99* and other newly identified races. It implies therefore that the stem rust pathogens have the potential to cause a wheat production disaster that would sourly affect food security (Singh et al., 2011).

Disease assessment is an essential task in the study of plant disease epidemics and vital to the knowledge of whether disease management practices are successful (Campbell and Neher, 1994). Disease severity evaluation is an important decision support for adoption of strategies and tactics for disease control. The most commonly used method to assess disease severity is visual (Bade and Carmona, 2011). Disease severity is determined by a function of the degree of infection, colonization, and damage of host tissues. Besides the amount of host development and growth is a function of disease severity (Gaunt, 1995).

Integrated disease management (IDM), which combines biological, cultural, physical and chemical control strategies in a holistic way of disease control as opposed to using a single component strategy is a better option apart from being sustainable (Khoury and Makkouk, 2010). It can be defined as a decision-based process involving coordinated use of multiple tactics for optimizing the control of the pathogen ecologically and economically (Khokhar and Gupta 2014). In practice and in most cropping systems today, emphasis is still being placed on a single technology (Khoury and Makkouk, 2010). Many problems have been associated with the use of fungicide such as the frequent emergence of fungicide resistance in pathogens and the harmful effects of fungicides to human health and the environment (Khoury and Makkouk, 2010).

Wheat production in Kenya mainly takes place on large- and medium-scale farms, using capital intensive technology. The technology on the medium- and large-scale farms is the same as that in Western Europe (Monroy et al., 2013). In contrast, small scale farms operations are smaller as compared to the large and medium (Monroy et al., 2013). The small scale wheat farmers complain of prohibitive production expenses and low production (caused by use of non-certified seeds and low use of inputs) and sub-regionof land as a major problem (MOA, 2013). Most large scale farmers are still holding stakes of wheat (Monroy et al., 2013). The cost of key inputs such as seed, pesticides is high for resource-poor farmers. Such high costs lead to low application and adulteration of inputs (GOK, 2010).

The main aim of this study was to assess the differences in disease incidence and severity in the major growing regions. The information on disease levels as connected with the farming practices' being carried out in the regions was not there. Therefore, the survey conducted was to determine the effectiveness of the management and control measure used in the regions.

METHODOLOGY

General information and percentage of the surveyed regions

A survey was conducted in three regions of Nakuru county, Njoro, Mau-Narok and Kabatini regions which represented 25.7, 35.1 and 39.2% respectively of the study area (Figure 1). The surveyed fields were early planted by the farmers during the 2015 season. In Mau-Narok, there were two major cropping seasons, early and late while, Njoro and Kabatini had one which were planted early. Only the fields with the early crop were surveyed in Mau-Narok. Most growers' small scale had planted early in Mau-Narok while most medium and large scale farmers planted late.

The locations surveyed in Mau-Narok region were Sururu, Mwisho Wa Lami, Likia and Mau-Narok. Mau-Narok had an average annual rainfall of 1300 mm, an altitude of 2900 m above sea level (masl), minimum and maximum temperatures range of 14°C and 26°C, respectively (Jaetzold et al., 2010) The second region was Njoro which had five locations mainly Piave, Lower Piave, Njoro and Kerima. Njoro region had an altitude of 2185 masl, average annual rainfall of 935 mm, and minimum and maximum temperatures of 9.7°C and 23.5°C, respectively. The third region was Kabatini having four locations mainly Karunga, Ngecha, Thayu and Ruguru which had many wheat growers. Kabatini had an altitude at 2135 masl with a minimum temperature of 10€C and maximum temperature of 26°C, and annual rainfall of 800 mm (Jaetzold et al., 2010).

Field survey

A questionnaire check list was used during the study. The part one of the questionnaire was about the general information, the name of the division, location and farm classification. Farm classifications were mainly three; small (<10 ha), medium (10-60 ha) or large scale (>60 ha) farms, adapted from MOA (2006). The second part of the questionnaire was about the farming practices in place, fungicide used, rate used and number of sprays. The other questions were about the wheat varieties commonly grown (FAO-SEC, 2012).

Sample size for disease assessment

A multi stage sampling technique was applied where fields were

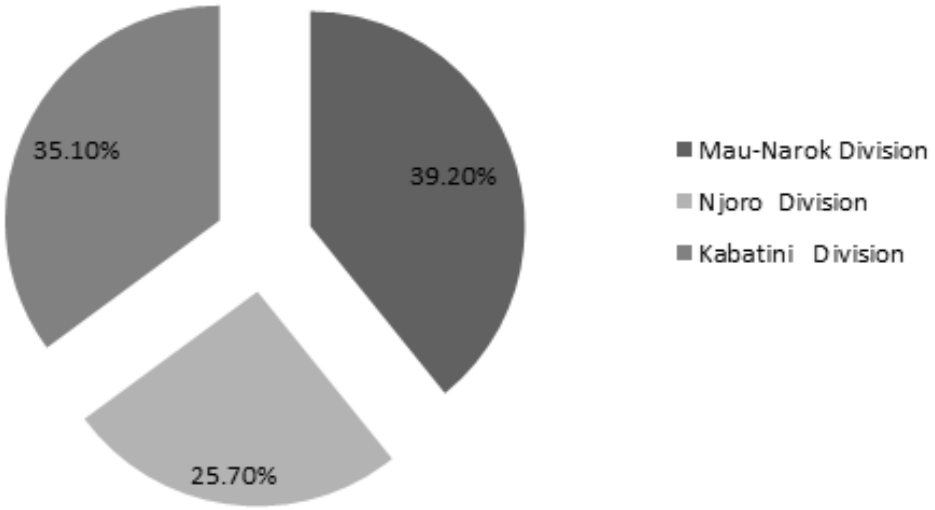

Figure 1. The frequency of fields surveyed in the three regions of three regions of Nakuru county, Kenya in 2015.

grouped as small, medium and large scale in the three regions of Mau-Narok, Njoro and Kabatini. The sample size of growers selected was done following the formula from Krejcie and Morgan (1970) as shown below;

$$S = \frac{X^2 NP(1-P)}{d^2(N-1) + X^2 P(1-P)} \quad (1)$$

S = required sample size, X^2 = the table value of chi-square for 1 degree of freedom at the desired confidence level (3.841), N = the population size, P = the population proportion (assumed to be 0.50 since this would provide the maximum sample size), d = the degree of accuracy expressed as a proportion (0.05). The total sample size was 58 in Mau-Narok, 38 in Njoro and 52 in Kabatini regions.

Assessment of disease intensity using incidence and severity percentages

A quadrate of 1 m by 1 m was used for both disease incidence and severity on the same field, and 1 m^2 used to obtain the two disease values. The incidence was the number of plant infected by disease and severity the percentage of foliage attacked by disease on the same plant. The stage of the wheat crop assessed was Zadoks GS 73 (early milk), GS 75 (medium milk), GS 77 (late milk), GS 83 (early dough) and GS 85 (soft dough) (Zadoks *et al*., 1974) which was wide-ranging from field to field across the study areas.

Disease incidence for three study areas

A quadrate was cast in the field randomly for the total number of farms visited. The proportion of stem rust infected plants to the total number of plants in the quadrate was calculated from the FAO-SEC (2012) formula as shown below:

$$DI = \frac{Number\ of\ diseased\ plants\ in\ the\ quadrate}{Total\ number\ of\ plants\ in\ the\ quadrate} * 100$$

Disease severity for three study areas

The same fields and plants used for disease incidence determination were scored for disease severity. Disease scoring was done following the modified Cobb scale as described by Peterson et al. (1948).

Data analysis

Data was input for analysis using the descriptive statistics, frequencies and cross tabulation. The frequencies were in percentages for all the entities. The entities included regions, locations, farm classification, fungicides used, the rates and number of sprays. The percentage for varieties grown, fertilizer use, seed source and a yes and no response for wheat grain yield as being high, medium and low was done. Each component was worked out in percentages among the three regions and arranged in tables accordingly.

RESULTS

Stem rust disease incidence

Data illustrated in Figure 2 revealed that Mau-Narok as having high levels of disease incidence, Kabatini having moderate to low and Njoro low. In Mau-Narok region, stem rust disease was observed in Sururu whose disease incidence were 12.8 to 23.5% and Mwisho Wa Lami 58.5%. Mau-Narok location had 7.9 to 60.3% and Likia location had 12.6 to 77.8%. In Njoro region, all the locations had no stem rust disease incidences. At Kabatini stem rust disease incidence occurred in Ngecha at 9.2 and 11.3% and Ruguru at 13.9% and 3.3%. The average disease incidence in Mau-Narok was 32.1 %, Kabatini 7.9% and Njoro 0%. The absence of disease in Njoro (Figure 2) was explained by the growers as an

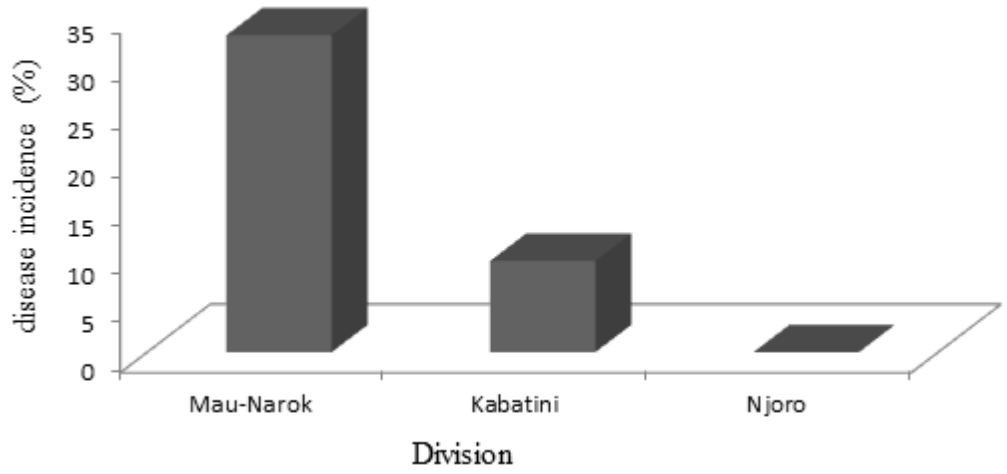

Figure 2. The average disease incidence (%) occurrence in the three regions of Nakuru county, Kenya in 2015.

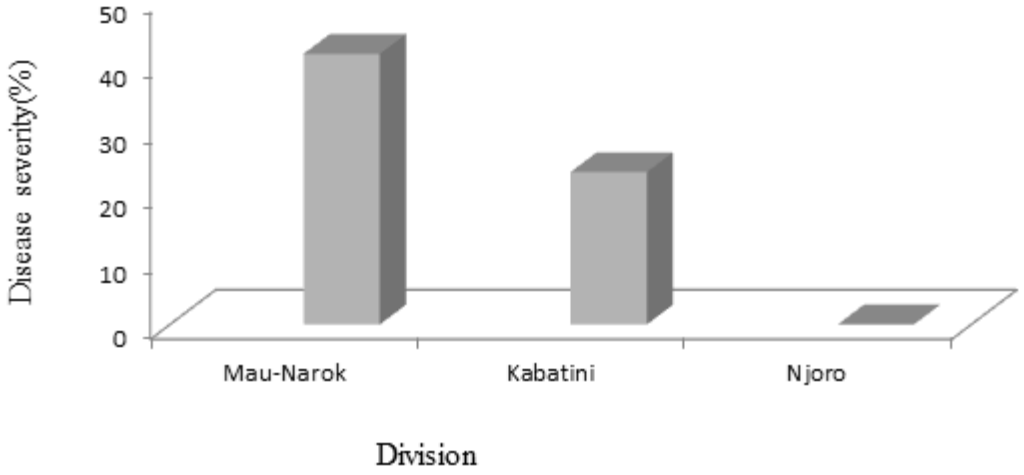

Figure 3. The average disease severity (%) occurrence in the three regions of Nakuru county, Kenya in 2015.

escape due to the changing rainfall patterns.

Stem rust disease severity in the three study areas

In Mau-Narok region, stem rust disease occurred in Sururu, where disease severity levels ranged from 30 to 40% and Mwisho Wa Lami had 20%, while Mau-Narok had upto 30 to 60%. In Likia, the disease severity was 40 to 60%. The disease severity in Mau-Narok was high by the figures obtained from one location to another. Kabatini reported stem rust disease severity in Ngecha was in the range of 20 to 30%. The figures in Kabatini showed that the disease severity levels were low. In Njoro region, all the locations surveyed had no stem rust disease severity. The average disease severity in the three regions was Mau-Narok 41.4%, Kabatini 23.3% and Njoro 0% (Figure 3).

Fungicide use, spraying rates and number of sprays in association with stem rust disease incidence

The number of sprays per growing season in Mau-Narok was observed at 34.5% of the growers spraying once, 34.5% of the farmers sprayed twice while 17.2% of the farmers sprayed thrice (Figures 4 and 5). About 42.1% of growers in Njoro did not spray fungicide on the wheat fields. Few growers (5.3%) used the earlier mentioned recommended rates, recommended rates were 52.6%

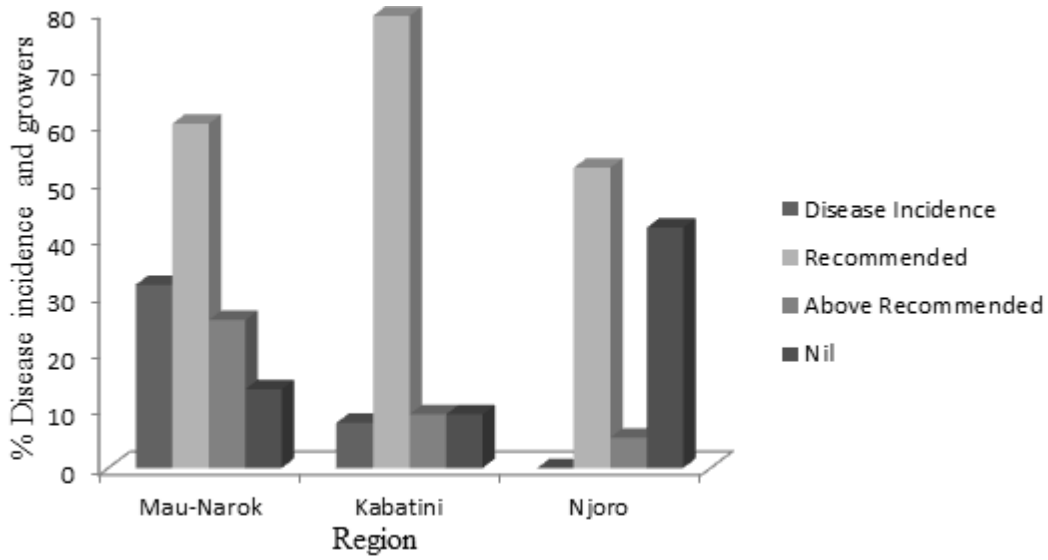

Figure 4. Fungicide spraying rates.

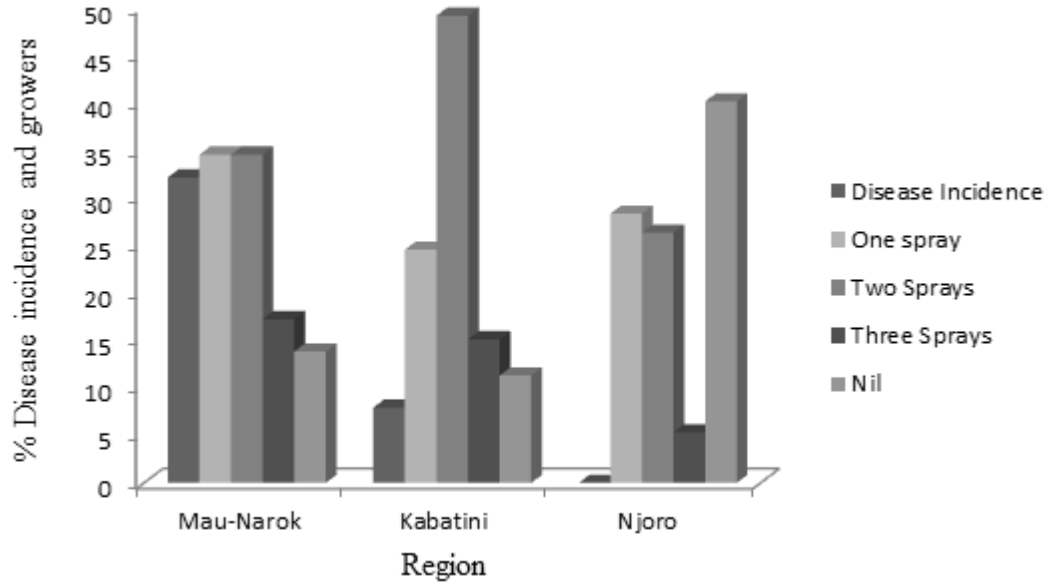

Figure 5. Disease incidence and number of fungicide sprays per growing season.

due to disease escape. In Njoro, few growers sprayed their fields once (28.9%). About 26.3% sprayed twice, and 2.6% sprayed thrice. The frequency of farmers who did not spray their field stood at 42.1% (Figure 4 and 5). In Kabatini, 9.4% used the earlier mentioned recommended rates, the recommended rates were at 79.2%, and those who did not spray at 11.3%. In Kabatini, 24.5% sprayed once, 47.1% twice, 15.1% sprayed thrice and 11.3% no spray (Figure 4 and 5).

The connection between the number of sprays and disease incidence percentage is shown in Figure 6, where the two sprays per growing season had 0 to 13.8% and three sprays had 0%, one spray had 36.8 to 77.8% diseases incidence. A higher percentage of growers using fungicides were found in Mau-Narok, followed by Kabatini and Njoro. As compared to Njoro and Kabatini, Mau-Narok had the highest percentage of growers of the earier mentioned recommended rates which were 5.3, 9.4 and 25.9%, respectively. Njoro regionhad a great number of fields that were not sprayed at 42.1% as compared to Mau-Narok 13.8% and Kabatini 11.3%. Despite the use of the earlier mentioned recommended

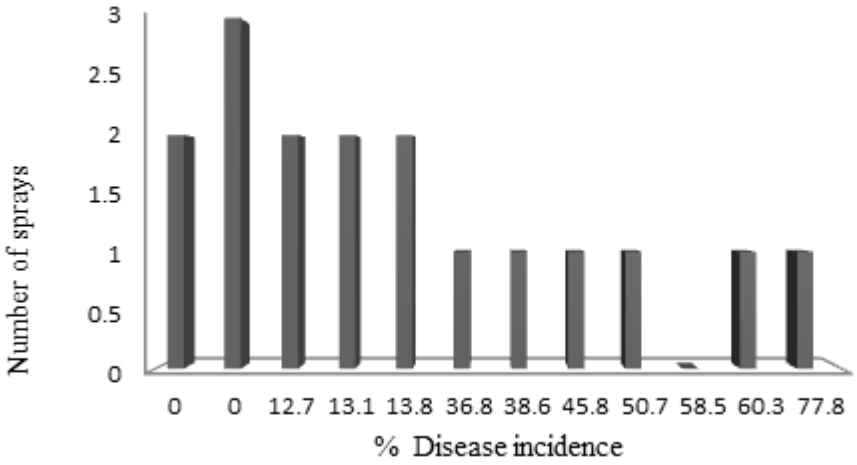

Figure 6. The association between number of sprays per growing season and disease incidence.

rates by growers in Mau-Narok disease incidence was moderate to high (Figure 2). In Njoro, during the growing season there was no disease, and growers sprayed only once or did not spray. In Kabatini, most of the growers sprayed twice at the recommended rates.

Varieties grown and seed source in association to stem rust disease incidence

Mwamba variety of certified seed was grown in Mau-Narok region where disease incidence of 23.5% was observed. In the same region, the fields with 12.8 and 13.3% disease incidence were planted with certified seed of the variety Robin. The field with 7.9, 12.6 and 18.8% disease incidence had certified seed of the variety NjoroBWII. The field with disease incidence at 19.8% was planted with certified seed of the variety Heroe (Figure 7 and 8). In Kabatini, the crop with disease incidence of 3.9, 11.3 and 9.2% had certified seed of variety Robin. The field with 3.3% disease incidence in the same region was planted with certified seed of variety NjoroBWII (Figures 7 and 8).

The field that reported the highest disease incidence of 77.8% was found in Mau-Narok region planted with uncertified seed of the variety Mwamba. The same region reported 38.6, 50.7, 58.5 and 60.3% disease incidence on the crops having uncertified seed of variety NjoroBWII. The field with 45.8% disease incidence was planted with uncertified seed of variety Robin (Figures 7 and 8). The percentage of growers using uncertified seed in Mau-narok was 70.7%, Njoro 23.7% and Kabatini 22.6% (Figures 7 and 8). The region with many gowers using certified seed was Kabatini 77.4%, Njoro 76.3% and Mau-Narok had the least percentage of 29.3%.

In the Mau-Narok region, the growers who planted the variety NjoroBWII was 53.4%, followed by Robin at 27.6%, Eagle10 at 1.7% and Korongo 1.7%. Mwamba was at 5.3% and Kwale 5.2%. The varieties Heroe, Ngami and Farasi were only found in Mau-Narok. In Njoro region, the growers have the following varieties: NjoroBWII (23.6%), Robin (34.2%), Mwamba (23.6%), Eagle 10 (2.7%) and Korongo (7.9%). Duma (2.6%) was the only variety grown in Njoro division and Kwale (5.4%). In Kabatini, the growers with Robin were 64.2%, NjoroBWII was 22.5%, Korongo was 5.7%, Kwale was 5.7%, Duma was 0% and Mwamba was 0% (Figure 9).

Cropping systems

In Mau-Narok, 100% of the growers used a rotation of wheat and peas or wheat and potatoes. In Njoro, 94.7% used a rotation of Maize and wheat, and 5.3% of growers were found using an intercrop of wheat and Boma rhodes grass. It was the only region where wheat was intercropped. In Kabatini, 100% used a rotation. The rotation involved wheat, tomatoes or wheat, beans, Kales instead of tomatoes (Figure 10).

DISCUSSION

The stem rust disease incidence in the three regions showed that there were many factors that were related to the % disease observed. For the entire study, areas incidence ranged from 3.3 to 77.8%. According to FAO-SEC (2012), incidence of over 40% is regarded as high. This implies that in Mau-Narok, stem rust disease incidence of 45.6 to 77.8% was high (Figure 2). In Kabatini area, the disease incidence was low at 3.3%. The factors that affected disease incidence levels were

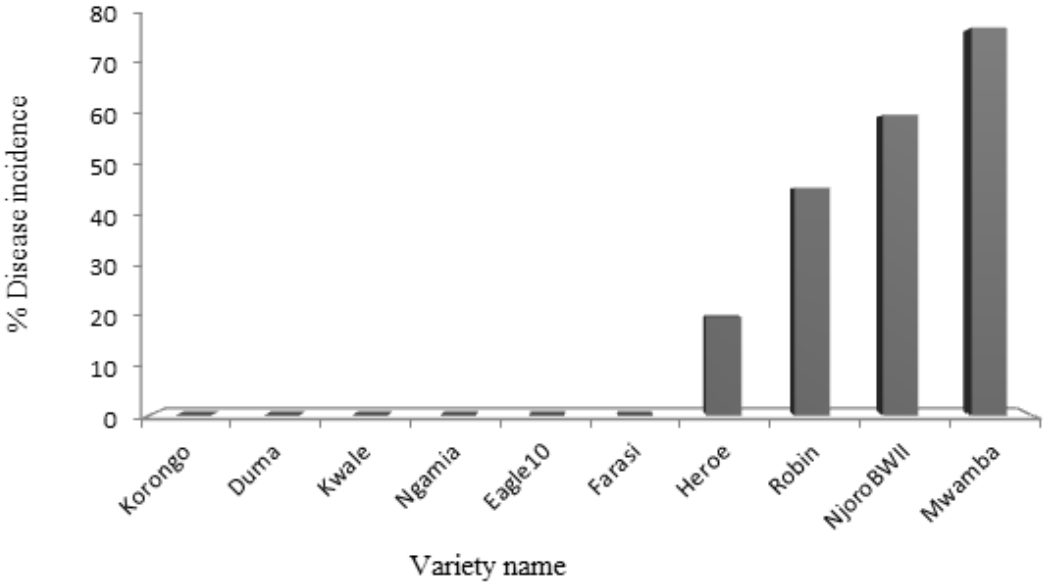

Figure 7. Variety of uncertified seed and disease incidence percentage.

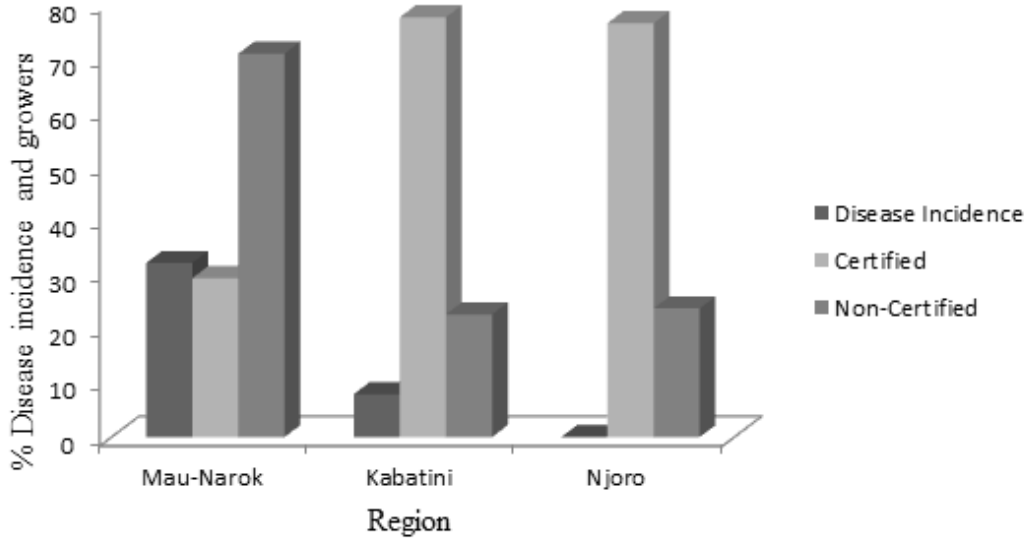

Figure 8. Disease incidence and seed source of certified or uncertified.

variety grown, fungicide use such as the rate of spray, number of sprays, seed source and crop management. In the case where the disease incidence is 77.8% in Mau-Narok, the crop was weedy, uncertified seed of variety Mwamba was used and one spray was done. The implication is that crop management and production process may affect the level of disease incidence. The fields with disease incidence ranging from 38.6 to 77.8% showed uncertified seeds were used and disease was not controlled using the right recommended spraying regimes.

The fields of Kabatini or Mau-Narok with disease incidence ranging from 0 to 12.8% had certified seed of the varieties Mwamba, Korongo, Robin and NjoroBWII being popular. The same fields were sprayed twice or thrice with a fungicide at the recommended rates (Figure 5 and 6). However, in Mau-Narok where 25.9% of growers sprayed at above the recommended rate was a sign of stem rust disease weighing heavily on growers' management attempts.

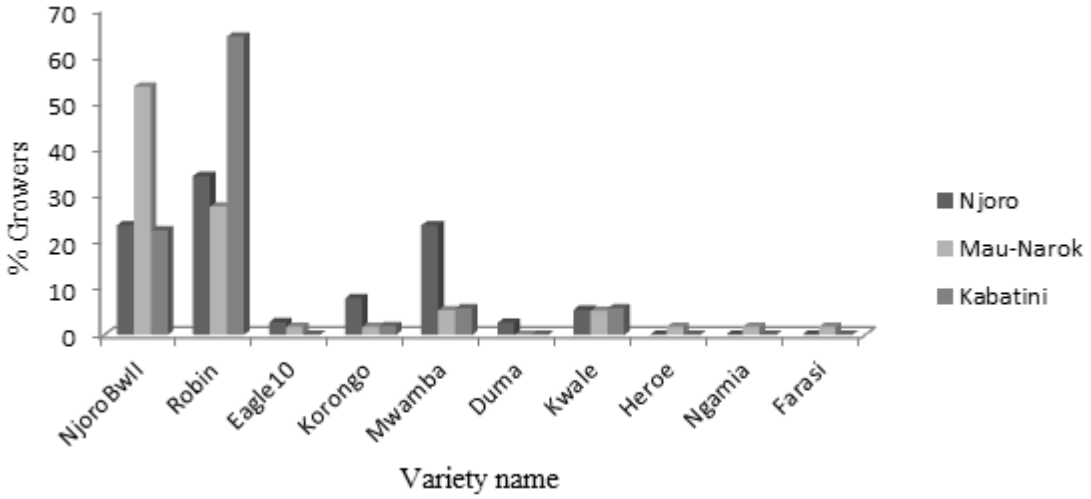

Figure 9. The percentage of varieties commonly grown in the three regions.

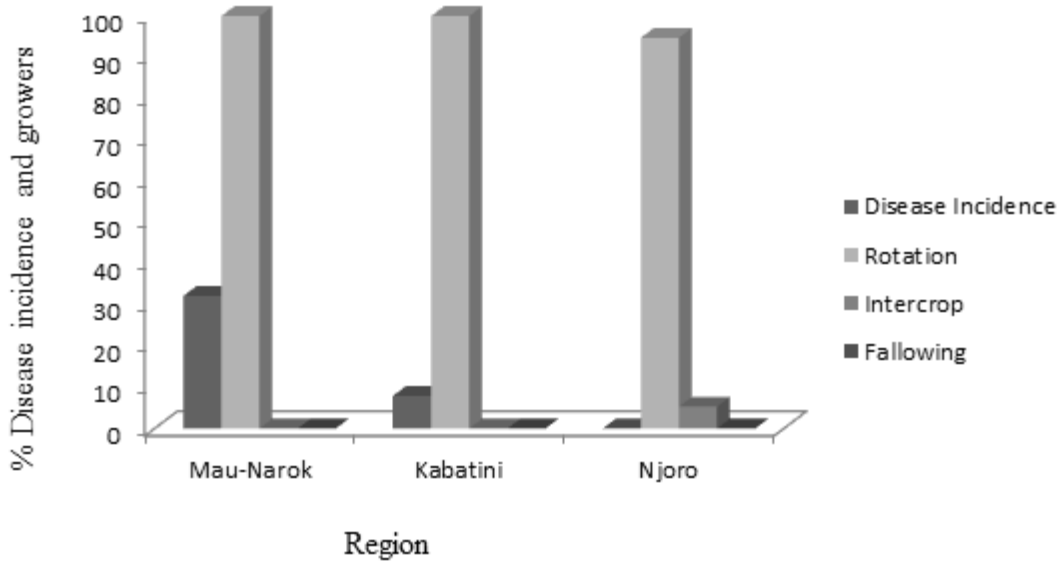

Figure 10. Cropping systems in the regions and disease incidence.

The stem rust disease severity in all the regions ranged from 20 to 60%. According to Taye et al. (2014), 0 to 20% indicates low disease severity, 21 to 40% is medium while greater than 41% is considered as high. Disease severity was high in Mau-Narok, low in Njoro and medium to low in Kabatini. The trend of disease severity was similar to disease incidence. However, fungicide use, spraying rates, number of sprays and varieties grown determined the severity levels. The fields sprayed twice or thrice with recommended or above the recommended rate reported medium to low severity of stem rust disease.

The number of fungicide sprays also affected disease incidence or severity. Prabhu et al. (2003) reported that two applications of tricyclazole or benomyl controlled panicle blast in rice, as indicated by lower values of disease progress curve and relative panicle blast severity, and increased grain yield. Ganesh et al. (2012) observed that three fungicide applications in rice Tricyclazole or Ediphenphos or Kitazine sprayed thrice at weekly interval managed leaf blast disease in rice. The percent use of fungicides in Mau-Narok was 43.2%, Kabatini 38.9% and Njoro 17.8%. The percentage of fungicide use reflected well with the disease pressure that was being experienced in the three regions with Mau-Narok being the most affected.

Fungicide application as described by Ghazanfar et al.

(2009) had an effect on the yield of Paddy rice Rabicide, particularly three applications resulted in increased yield. Gianesssi and Reigner (2005) stated that more effective fungicides have been introduced and used by growers to prevent losses caused by fungal pathogens, and Tadesse et al. (2010) also proved that fungicide treatments have effectiveness in reducing disease severity. As stated by Wegulo et al. (2012) fungicides used to control foliar fungal diseases of wheat belong to two major classes with a broad spectrum of activity against fungal pathogens. Fungicide application by the growers was not clear whether the spraying was done before or after disease onset. As explained by Balardin et al. (2010) fungicide application prior to any contact between pathogen and host is considered to be preventative. After inoculation and just before initial symptoms, the application is curative. All applications made after the onset of symptoms is eradicative. There is therefore a need of fungicide technologies to substantiate on the effective use and control of stem rust disease.

All the commonly grown varieties were released as resistant to wheat stem rust but resistance has been breaking down over the years due to mutation of the fungal pathogen. The two most commonly grown varieties across the three regions were Robin at 41.2% and NjoroBWII at 35.1%. The other varieties Mwamba (10.1%), Duma (5.4%) and Korongo (3.4%) were also found across the regions. High disease incidence and severity were found in the fields with Robin and NjoroBWII which appeared to have become susceptible to stem rust. Generally, the fields with Korongo, Duma and Kwale did not report any disease incidence largely due to the number of fungicide sprays used which was twice or thrice as recommended. The low disease incidence could be attributed to genetic resistance which according to Park, (2008) remains the most economical means of rust control. Resistant cultivars also contribute significantly to reducing off-season rust survival. Similarly, Singh et al. (2011) suggested that reducing the area currently occupied by susceptible wheat varieties should become the highest priority.

According to the growers, wheat varieties tend to be replaced for disease management purposes rather than market preference. The two most commonly preferred varieties by the growers in all the areas were Robin (59.1%) and NjoroBWII (40.9%) across the three regions. In contrast, varieties Mwamba, Kwale and Korongo were preferred by 10.1, 5.4 and 3.4% of the farmers respectively. This implied that most farmers preferred old varieties as compared to the newly released varieties. The farmer preference was based on yield and seed quality attributes rather than the disease reaction by the variety.

The most common cropping system in the three regions was wheat legume rotation. In Mau-Narok region farmers practiced wheat/peas and wheat potato rotation. The major crop rotation in Kabatini was a rotation of wheat and beans or wheat tomatoes. In Njoro, a rotation of wheat and maize was preferred. Overally, 100% of farmers in Mau-Narok practiced crop rotation while 94.7% and 5.3% of the farmers did the same in Kabatini and Njoro respectively. Crop rotation as reported by Khoury and Makkouk, (2010) is one of the most important means of managing disease in small grains. Cultural control methods such as crop rotations, fertilizer use and certified seed not only serve in promoting the healthy growth of the crop, but are also effective in directly reducing disease inoculums potential. Besides, crop rotation enhances the biological activities of antagonists in the soil.

Three of wheat fields in Njoro region lower Piave location had an intercrop of wheat and Rhodes grass which according to FAO (www.fao.org) is defined as planting alternating rows of maize and beans, or growing a cover crop in between the cereal rows. FAO (www.fao.org) also reported that the practice is not beneficial because an intercrop may compete with the main crop for light, water and nutrients. This may reduce the grain yields of both crops.

Fallowing was not observed in the three regions. This could be due to the fact that land scarcity is compounded by low soil fertility as was observed by Mwangi (1996). This has resulted in the shortening or elimination of the fallow period without concurrent efforts to increase soil nutrients through fertilizer application or other soil management practices mainly found in Sub Saharan Africa.

Seed quality is critical for crop establishment and plant vigour. Clean seed ensures field hygiene. About 59.1% of farmers interviewed used certified seed while 40.9% used non-certified seed. Mau-Narok (70.7) had the highest number of farmers using non-certified seed followed by Njoro (23.7%) and Kabatini at (22.6%) in that order (Fig. 10). The fields with certified seed had lower or no cases of stem rust disease as the case in Kabatini where 11.3% disease incidence was reported.

Conclusion

Stem rust disease incidence and severity % were reportedly high in Mau-Narok, followed by Kabatini which had low levels and Njoro having none. However, the disease incidence and severity was associated with the management practices. Two or more sprays at the recommended or above recommended rates showed either no or low disease incidence or severity. In addition, the variety grown and seed quality determined disease incidence and severity. The use of uncertified seeds of susceptible varieties increased disease levels. A multi-tactic approach involving optimal use of fungicides, resistant varieties, quality certified seed and crop rotations with legumes would be the best option for stem rust disease control. Similarly, as a result of diminishing

land sizes under wheat (crops) farming practices in place have to be intensified and maximized based on modern agricultural technologies for food security. Work needs to be done on the verification and validation for an effective integrated disease management approach for stem rust disease.

Conflict of Interests

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENT

The study was supported by the East Africa Agricultural Productivity Project (EAAPP) and Kenya Agricultural Livestock and Research Organization (KALRO).

REFERENCES

Bade CIA, Carmona AM (2011). Comparison of methods to assess severity of common rust caused by *Puccinia sorghi* in maize. Trop. Plant Pathol. 36(4):264-266.

Balardin R, Madalosso Debortoli M, Lenz G (2010). Factors Affecting Fungicide efficacy in the Tropics. *In*: Fungicides, Odile Carisse (Ed.) InTech, ISBN: 978-953-307-266-1 pp. 23-38.

Campbell LC, Neher AD (1994). Epidemiology and management of root diseases. Springer-Verlag Berlin Heidelberg pp. 117-147.

Curtis T, Halford NG (2014). Food security: the challenge of increasing wheat yield and importance of not compromising food safety. Ann. Appl. Biol. 164:354-372.

FAO (2012). Crops and Cropping systems. http://www.fao.org/ag/ca/../06CROP1.PDF. Accessed 18/11/2015. 3.00pm

Ganesh NR, Gangadhara NB, Basavaraja NT, Krishna NR (2012). Fungicidal management of leaf blast disease in rice. Global J. Bio-sci. Biotechnol. 1(1):18-21.

Gaunt RE (1995). The relationship between plant disease severity and yield. Ann. Rev. Phytopathol. 33:119-44.

Ghazanfar UM, Wakil W, Sahi TT, Yasin S (2009). Influence of various fungicides on the management of rice blast disease. Mycopathology 7(1):29-34.

Gianessi PL, Reigner N (2005). The Value of Fungicides in U.S. Crop Production. CropLife Foundation. Crop Protection Research Institute. USA.

GOK (2010). Agricultural sector development strategy 2010–2020.

Jaetzold R, Schmidt H, Hornetz B, Shisanya C (2010). Farm Management Handbook of Kenya. Volume II, Part B: Natural Conditions and Farm Management Information, Central Kenya (Rift Valley and Central Provinces) pp. 379-404.

Khokhar KM, Gupta R (2014). Integrated Disease Management. Pop. Kheti 2(1):87-91.

Khoury W, Makkouk K (2010). Integrated Plant Disease Management in developing countries. J. Plant Pathol. 92(4):35-42.

MOA (Ministry of Agriculture). (2006). Millennium development goals, needs assessment report. Republic of Kenya requirements for goal no. 1: Eradication of extreme poverty and hunger. Ministry Agric. Collaboration Ministry Plan. Natl Dev.

MOA (Ministry of Agriculture). (2013). Food security assessment reports. Department of crops management. MOA/CRP/FIELD/01/20.

Monroy L, Mulinge W, Witwer M (2013). Analysis of incentives and disincentives for wheat in Kenya. Technical notes series, MAFAP, FAO, Rome

Mwangi W (1996). Low Use of Fertilizers and Low Productivity in Sub-Saharan Africa. NRG Paper , CIMMYT, Mexico, D.F: 96-05.

Njau NP, Wanyera R, Macharia KG, Macharia J, Singh R, Keller B (2009). Resistance in Kenyan bread wheat to recent Eastern African isolate of stem rust, *Puccinia graminis* f.sp. *tritici, Ug99.* J. Plant Breed. Crop Sci. 1(2):22-27.

Park FR (2008). Breeding cereals for rust resistance in Australia. Plant Pathol. 57:591-602.

Peterson RF, Campbell AB, Hannah EA (1948). A diagrammatic scale for estimating rust intensity of leaves and stem of cereals. Can. J. Res. 26:496-500.

Prabhu SA, Filippi CM, Zimmermann PJF (2003). Cultivar response to fungicide application in relation to rice blast control, productivity and sustainability. Pesqui. Agropecu. Bras. 38(1):11-17.

Shiferaw B, Smale M, Braun H-J, Duveiller E, Reynolds M, Muricho G (2013). Crops that feed the world 10. Past successes and future challenges to the role played by wheat in global food security. Food Security, Springer 5(3):291-317.

Singh PR, Hodson PD, Huerta- Espino J, Jin Y, Bhavani S, Njau P, Herrera-Foessel S, Singh S, Govindan V (2011). The emergence of *Ug99* races of stem rust fungus is a threat to world wheat production. Ann. Rev. Phytopathol. 4:465-81.

Tadesse K, Ayalew A, Badebo A (2010). Effect of fungicide on the development of wheat stem rust and grain yield of wheat varieties in highlands of Ethiopia. Afr. Crop Sci. J. 18(1):23-33.

Taye T, Fininsa C, Woldeab G (2014). Importance of wheat stem rust, (*Puccinia graminis* f.sp. *tritici*), in Guji zone, Southern Ethiopia. Plant 2(1):1-5.

USAID (2010). Staple foods value chain analysis. Country Report. Kenya.

Wegulo S, Stevens J, Zwingman M, Baenziger PS (2012). Grain yield Response to Foliar Fungicide Application in Winter Wheat. *In*: Fungicides for Plant and Animal Diseases, Dr. Dharumadurai Dhanasekaran (Ed.). InTech, ISBN: 978-953-307-804-5 pp. 227-244.

Zadok JC, Chang TT, Konzak CF (1974). A decimal code for the growth stages of cereals. Weed Res. 14:415-421.