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EFFECT OF ABIOTIC AND BIOTIC STRESS AND CROP MANAGEMENT ON HEALTH CONDITION AND YIELD OF CEREALS

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Abstract

Wheat production has become a global problem due to the climate change impact on wheat farming systems, pest management and control. Yield loss predictions are usually made by using regression models with either biotic or abiotic factors as predictor variables, but only a few of them have considered the combined effects of multiple diseases and climatic conditions. Moreover, efficacy of fungicides in pest control and their effect on yield increase is usually analysed in respect to the level of disease index and yield achieved in untreated plots, without taking into consideration the influence of other environmental elements. This study was conducted in order to determine the combined effects of biotic factors (disease indices) and abiotic factors (climatic elements and efficacy of fungicides) on yield achievements of winter wheat varieties. Field trials were set up under naturally occurring inoculum of the prevalent economic pathogens of wheat in the period 2006-2017. Model varieties Barbee and Durumko, known to have various degrees of susceptibility to wheat pathogens, were used in the study. General linear model function of Minitab 17 (trial version) was used for all the analyses. It was determined that yield loss in untreated plots was significantly influenced by the combined effects of multiple diseases and climatic elements. Moreover, it was determined that the relationship between fungicide efficacy and yield achievements was not straightforward and that it should be analysed in respect to the combined effects of biotic and abiotic factors.

Key words: *wheat, fungicide efficacy, yield gain, rusts of wheat, abiotic factors*

INTRODUCTION

Wheat production has become a global problem due to the climate change impact on wheat farming systems, pest management and control. Analysis of the most influencing factors on yield losses is in the focus of scientific community, knowing that yield is a complex trait. Moreover, agro-ecological conditions, resistant varieties and applied pesticides influence changes in population structure of wheat pathogens making wheat breeding for resistance to economically important diseases very challenging.

The occurrence of obligate parasites (*Blumeria graminis* f. sp. *tritici*, *Puccinia triticina*, *Puccina striiformis* f. sp. *tritici*) and crop residue-borne necrotrophic pathogens (*Zymoseptoria tritici*) in Serbia has been monitored through the decades in experiments related to fungicide efficacy and resistance testing of wheat varieties (Jevtić et al., 2017). Many efforts have been directed to determining the most influencing factors on damage thresholds caused by pathogenic infection and their impact on yield and yield components losses. Although chemical treatments were proven to be a powerful disease-control tool, followed by increases in yield, the question regarding how climate change would influence efficacy of fungicide applications still remains unanswered (Magan et al., 2011).

Knowing that the relationship between disease rating scale and yield loss is not straightforward (Duveiller et al., 2007; Jevtić et al., 2017), and that fungicide treatment could exhibit negative effect on plant growth when applied under unfavourable environmental conditions (Ferree et al., 1999), the main objective of this study was to evaluate the combined effects of biotic factors (disease indices) and abiotic factors (climatic elements and efficacy of fungicides) on yield achievements of winter wheat varieties. The data related to the period 2006 - 2017 were analysed and characterized in terms of agro-ecological conditions of Serbia.

MATERIAL AND METHODS

The fungicide efficacy trials were conducted in the locality Rimski Šančevi (Vojvodina, northern province of Serbia) over the period 2006-2017 using soft wheat variety Barbee (*Triticum aestivum* ssp. *compactum*), and hard wheat variety Durumko (*Triticum turgidum* subsp. *durum*). Variety Barbee is known for its increased susceptibility to wheat rusts and powdery mildew, while Durumko is usually used as a susceptible check for leaf blotch diseases.

Field trial and disease assessment

Field trials were set up in a randomized block design in four replicates with plot size of 10 m^2 under naturally occurring inoculum. Fungicides were applied at two growth stages: BBCH 36-37 (flag leaf just visible, rolled) and BBCH 51-59 (inflorescence emergence, heading) (Witzenberger et al., 1989; Lancashire et al., 1991). Usually, ten fungicide-sprayed and non-sprayed check treatments were included in field trial per year. Different types of active ingredients, such as amides, aromatics, azoles, benzimidazoles, morpholines, oxazoles, strobilurins, pyrazoles and pyridines, were applied in recommended dosage rates.

Assessments of leaf disease severity were made at the growth stage 71-73 BBCH (kernel watery; early milk) (Witzenberger et al., 1989; Lancashire et al., 1991), known to be highly related to yield (Wegulo et al., 2009). Assessments of powdery mildew, leaf rust, and yellow rust disease severity were made at the growth stage 71-73 BBCH (kernel watery; early milk) (Witzenberger et al., 1989; Lancashire et al., 1991) using modified Cobb's scale (Peterson et al., 1948). Disease severity of *Septoria tritici* blotch was assessed using the disease rating keys devised by James (1971). The disease indices of obligate and leaf blotch pathogens were calculated by taking into consideration incidence and severity (Cao et al., 2014).

Yield gain and fungicide efficacy

Yield was measured for each plot at 15 % water content. The yield gain (%) was determined as yield gain in treated plots compared with yield of untreated plots (Eq.1).

$$Y(\%)=((Y_1 - Y_2)/Y_2) \times 100$$

Y_1 - grain yield of fungicide treated plot
Y_2 - grain yield of the non-sprayed check treatment

Fungicide efficacy was calculated using Abbott's formula (Eq. 2)

$$\text{Efficacy } (\%)=((X-Y)/X) \times 100$$

X – disease severity in the non-sprayed check treatment;
Y – disease severity in the treated plot

Yield loss (%) was calculated as yield loss in untreated plots compared with the highest yield response of treated plots.

$$Y(\%)=((Y_1 - Y_2)/Y_1) \times 100$$

Statistical methods

General linear model was used to estimate the relationship between disease indices, abiotic factors and yield gain on fungicide treated plots in the period 2006–2017. Disease indices were considered biotic predictive variables, while monthly averages of temperatures, relative humidity, and total rainfall (http://www.hidmet.gov.rs/) together with fungicide efficacy were considered abiotic predictor variables in building regression models. General linear model was performed using Minitab 17 Statistical Software (2010) (trial version).

RESULTS AND DISCUSSION

Average yield of variety Barbee was 5.4 t/ha on treated and 4.4 t/ha on untreated plots resulting in average yield loss of 18.5 %. Yield of variety Barbee did not change linearly over the period 2006-2017 (Fig.1). The influence of the year (*P* <0.000) and treatments (*P* <0.000) on yield of variety Barbee was determined to be significant. Yield losses caused by obligate parasites varied considerably during 2006-2017 and were in range from 2.7 % in 2012 when average yield on un-treated plots was 7.2 t/ha to 44.2 % in 2009 when average yield on untreated plots was 2.5 t/ha. Jevtić et al. (2017) reported that the most influencing factors on yield loss of Barbee variety in 2006-2013 were disease index of leaf rust and temperature in April. In 2014, yellow rust predominated over leaf rust causing yield loss of 43.4 % on Barbee variety.

Durumko variety is known to have higher yield potential than Barbee variety. Average yield of Durumko variety on treated plots was 7.1 t/ha in 2006-2017. In untreated plots it was 6.8 t/ha, resulting in average yield loss of 4.2 %. Since difference between yield of treated and untreated plots was not as prominent as it was for variety Barbee, the influence of treatment (treated and untreated) was not recognized as significant, and variations in yield throughout the period were attributed to significant influence of the year (*P* <0.000).

Fungicide efficacy and yield loss of Barbee variety

Chemical treatments were proven to be a powerful tool for disease-control, followed by yield increase, however it was also evident that relationship between yield gain and fungicide efficacy is not always straightforward (Fig.1) and that is related to many factors including difference in disease pressure (Fig.2).

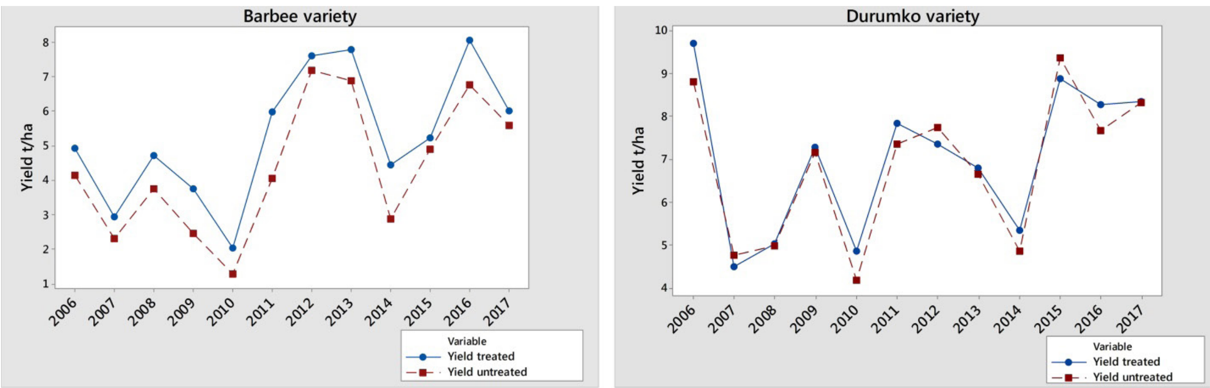

Figure 1. Yield of Barbee and Durumko varieties on treated and untreated plots

In the years when disease pressure of obligate parasites on Barbee variety was below 20%, yield gain in treated plots was not correlated with fungicide efficacy. In 2007 and 2008 when disease index of leaf rust and powdery mildew was below 20 % no evinced difference in yield gain in treated plots (27 % in 2007) and (26 % in 2008) was observed, although fungicide efficacy in controlling powdery mildew varied from 60 % (2007) to 90 % (2008) (Fig. 2). Average fungicide efficacy in controlling leaf rust in both years was nearly 100 %. Contrary to that, in 2010 disease index of leaf rust in untreated plots was also 20 % and fungicide efficacy was nearly 100 % as it was is in previous years, but yield gain was more than double higher and reached 63 %. In that year disease pressure of powdery mildew reached 35 % and fungicide efficacy of 70 % brought to yield gain on treated plots of 63 %.These results pointed out that the relation between fungicide efficacy against certain pathogen and yield gain in treated plots is influenced by many abiotic and biotic factors and should be analysed in respect to combined effects of them all. In addition, variability in yield gain in treated plots in the years when disease pressure does not exceed certain limits can be explained by the ability of plants to compensate negative effects of flag leaf infection. El Wazziki et al. (2015) reported that defoliation of flag leaves could improve the photosynthetic activity of the other leaves and that disease severity is not equivalent to the loss of the same percentage of green photosynthetic leaf area.

The fungicidal effect on Barbee yield gain was more prominent in the years when disease pressure took the range between 20-80 % for wheat rusts and 20-44 % for powdery mildew. Leaf and yellow rust with disease indices of 37–68 % were successfully controlled with fungicide efficacy of 66-79 % resulting in yield gain of 47-54 %. In the years when powdery mildew indices were between 30-35 % (2009-2011), yield gain in treated plots took the range of 47-64 % with evinced correlation with fungicide efficacy. However, it should be pointed out that fungicide efficacy in controlling powdery mildew varied from 7 % in 2011 to 70 % in 2010.

Under high disease pressure, which was on average 80 % for yellow rust in 2015, fungicide efficacy of 47 % resulted in Barbee yield gain of only 7 %. In that year, average powdery mildew disease index also reached the highest value (60 %) comparing with those in twelve-year period and was controlled with fungicide efficacy of 23 %. In 2016, average disease index of powdery mildew was 50 %, which was still higher than twelve-year average, and fungicide efficacy of 29 % resulted in yield gain of 19 %. Those results indicated that under severe disease pressure fungicidal effect could decrease disease index up to 50 %, but it would not be enough to achieve yield gain as in the years when no epidemic invasion occurs.

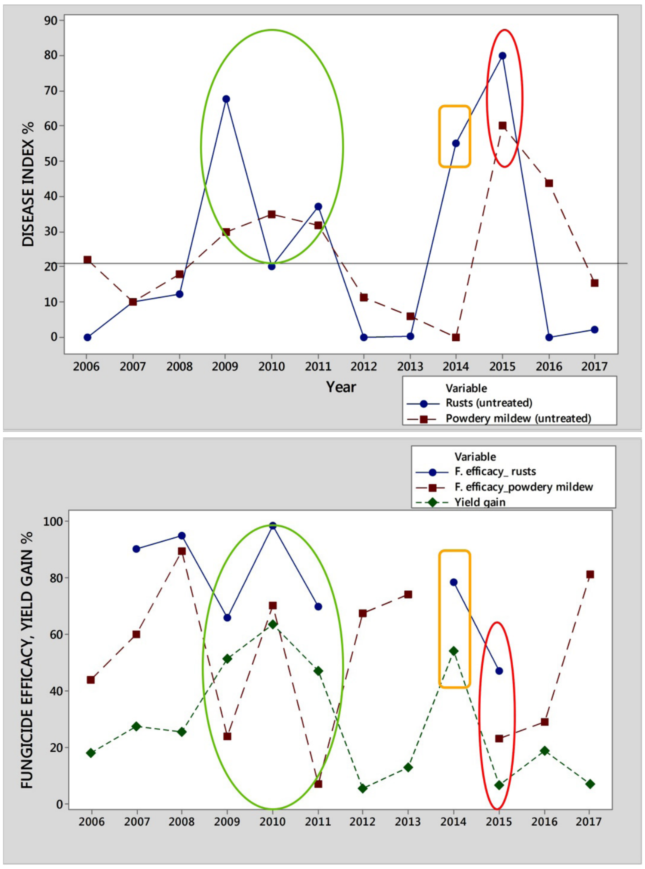

Figure 2. Relationship between disease index of obligate parasites, fungicide efficacy and yield gain of Barbee variety

In order to determine the most influencing factors on Barbee yield general linear model of Minitab 17 (trial version) was applied on data originating from both treated and untreated plots. Analysis of variance showed significant influence of the year (*P*<0.001), treatment (*P*=0.094), and fungicide efficacy against leaf rust (*P*=0.006) for the period 2006-2017 with the exception of 2014 and 2015 when yellow rust predominated over leaf rust. The regression model accounted for 88.5 % of variation in Barbee yield which is expressed in the term of coefficient of determination (R^2). In 2014 and 2015, disease index of yellow rust (*P*=0.016), average temperature in January (*P*=0.001), fungicide efficacy against yellow rust (*P*=0.015), and treatment (*P*=0.001) had significant influence on Barbee yield with R^2 of 67.8 %. Temperature in January was proven to be highly influencing on yellow rust epidemics (Sharma-Poudyal and Chen, 2011). In 2014, winter temperature in Serbia exceeded the ten-year average causing outbreak of Warrior race of yellow rust (Jevtić et al., 2017), causing Barbee yield loss of up to 43.4 %. The *P*-value (<0.001) for both regression models in the analysis of variance showed that the models are significant at an α-level of 0.05. An analysis of residuals showed the normal probability plot which evinced an approximately linear pattern that is consistent with a normal distribution.

Fungicide efficacy and yield loss of Durumko variety

Non-correlated dependence between fungicide efficacy and yield gain of Durumko variety was observed as it was when disease indices of obligate parasites on Barbee variety did not exceed 20 %. In twelve-year period, average disease index of *Septoria tritici* blotch on Durumko did not exceed 24.5 %, fungicide efficacy was higher than 58 %, except in 2016 when it was 2%, however yield gain in treated plots varied from 1 % to 22.5 % and was not correlated with fungicide efficacy (Fig. 3).

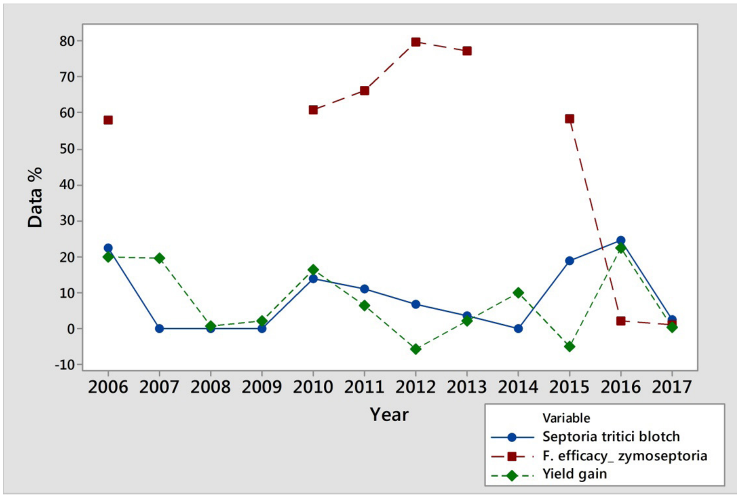

Figure 3. Relationship between disease index of *Septoria tritici* blotch, fungicide efficacy, and yield gain of Durumko variety

Durumko is known to be less susceptible to obligate parasites than Barbee so the leaf rust and powdery mildew were not considered as additional influencing factors on variation in yield achievements of Durumko. Jevtic et al. (2017) reported that in the period 2006-2013 yield loss of Durumko on untreated plots was 10 % and mostly influenced by disease index of *Septoria tritici* blotch and temperature in June, if agro-ecological conditions of Serbia were taken in consideration. In this study, influencing factors on yield achievements were analysed in respect to both untreated and treated plots, and it was determined that the difference between yield of treated and untreated plots was not as prominent as it was for Barbee. Moreover, in 2012 and 2015 average yield of untreated plots was higher than in treated plots. The possibility of overcoming the yield in treated plots by yield on untreated plots was also reported by Rodrigo et al. (2015). Rodrigo et al. (2015) pointed out that under Mediterranean conditions fungicide application might not be recommended in years drier than average, as severity of *Septoria tritici* blotch would be low and the fungicide application itself could reduce grain yield resulting in lower yield in treated than in untreated plots. In addition, Jevtić et al. (2017) reported that *Septoria tritici* blotch accounted for 37.2 % of variation in Durumko yield loss, which was in accordance with results reported by Berraies et al. (2014). Berraies et al. (2014) noted coefficients of determination of 39% and 44% in two sowing seasons while estimated grain yield losses caused by *Septoria tritici* blotch using 400 lines of durum wheat. Those results indicated that great variation in yield losses can be expected when *Septoria tritici* blotch index does not exceed 25 % and that environmental factors greatly contributed to the final yield achievements. In this study, the factors contributing to yield variation in both treated and untreated plots with R^2 of 71.6 % were: disease index of *Septoria tritici* blotch (P=0.005), fungicide efficacy (P=0.137), all climatic elements in March (P<0.001), and total rainfall in May (P<0.001).

CONCLUDING REMARKS

The results of this study indicated that the relationship between fungicide efficacy and yield achievements is not straightforward and is highly influenced by disease pressure.

The combined effects of biotic and abiotic factors influenced yield achievements in the treated plots and should be considered when fungicidal effects are estimated.

Further investigations of potential adverse effects of different types of active ingredients on crop physiology, especially on photosynthesis in changing climate conditions, will provide more information on quality and predictability of fungicidal effects on yield achievements in the future.

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REFERENCES

Berraies, S., Gharbi, M.S., Rezgui, S., & Yahyaoui A. (2014). *Estimating grain yield losses caused by Septoria leaf blotch on durum wheat in Tunisia*. Chilean Journal of Agricultural Research, 74 (4), 432-437.

Cao, X., Yao, D., Duan, X., Liu, W., Fan, J., Ding, K., & Zhou, Y. (2014). *Effects of powdery mildew on 1 000-kernel weight, crude protein content and yield of winter wheat in three consecutive growing seasons.* Journal of Integrative Agriculture, 13 (7), 1530-1537

Duveiller, E., Singh, R. P., & Nicol, J. M. (2007). *The challenges of maintaining wheat productivity: pests, diseases, and potential epidemics.* Euphytica, 157, 417–430.

El Wazziki, H., El Yousfi, B., & Serghat, S. (2015). *Contributions of three upper leaves of wheat, either healthy or inoculated by Bipolaris sorokiniana, to yield and yield components*. Australian Journal of Crop Science, 9(7), 629-637.

Ferree, D. C., Hall, F. R., Krause, C. R., Roberts, B. R., & Brazee, R. D. (1999). *Influence of pesticides and water stress on photosynthesis and transpiration of apple. Fruit crops: a summary of research 1998.* Ohio State University, Extension Research Circular, 299, 34–46.

James, W.C. (1971). *An illustrated series of assessment keys for plant diseases, their preparation and usage.* Canadian Plant Disease Survey, 51, 39-65.

Jevtić, R., Župunski, V., Lalošević, M., & Župunski, Lj. (2017). *Predicting potential winter wheat yield losses caused by multiple disease systems and climatic conditions.* Crop Protection, 99, 17-25.

Lancashire, P.D., Bleiholder H., van den Boom, T., Langelüddeke, P., Stauss, R., Weber, E., Witzenberger, A. (1991): *An uniform decimal code for growth stages of crops and weeds*. Annals of Applied Biology, 119:561–601.

Magan, N., Medina, A., & Aldred, D. (2011). *Possible climate-change effects on mycotoxin contamination of food crops pre- and postharvest.* Plant Pathology, 60, 150–163.

Minitab 17 Statistical Software (2010). [Computer software]. State College, PA: Minitab, Inc. (www.minitab.com)

Peterson, R. F., Campbell, A. B., & Hannah, A.E. (1948). *A diagrammatic scale for estimating rust intensity on leaves and stems of cereal.* Canadian Journal of Research, 26, 496-500.

Rodrigo, S., Cuello-Hormigo, B., Gomes, C., Santamaria, O., Costa, R., Poblaciones, M.J. (2015). *Influence of fungicide treatments on disease severity caused by Zymoseptoria tritici, and on grain yield and quality parameters of bread-making wheat under Mediterranean conditions.* European Journal of Plant Pathology, 141, 99–109.

Sharma-Poudyal, D., & Chen, X. M. 2011. *Models for predicting potential yield loss of wheat caused by stripe rust in the U.S.* Pacific Northwest. Phytopathology, 101, 544-554.

Wegulo, S. N., Breathnach, J. A., & Baenziger, P. S. (2009). *Effect of growth stage on the relationship between tan spot and spot blotch severity and yield in winter wheat.* Crop Protection, 28, 696–702.

Witzenberger, A., Hack, H., Boom, T. (1989): *Erläuterungen zum BBCH-Dezimal-Code für die Entwicklungsstadien des Getreides – mit Abbildungen.* Gesunde Pflanzen, 41:384-8.

ВЛИЈАНИЕ НА АБИОТСКИ И БИОТСКИ СТРЕС И МЕНАЏМЕНТ НА КУЛТУРА НА ЗДРАВСТВЕНАТА СОСТОЈБА И ПРИНОСОТ НА ЖИТНИТЕ КУЛТУРИ

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Резиме

Производството на пченица стана глобален проблем поради влијанието на климатските промени врз системите за одгледување на пченица, управувањето со штетници и контролата. Предвидувањата за губиток на приносот обично се прават со користење на регресивни модели со биотски или абиотски фактори како променливи варијабли, но само неколку ги земале предвид комбинираните ефекти на повеќе болести и климатски услови. Покрај тоа, ефикасноста на фунгицидите во контрола на штетници и нивниот ефект врз зголемувањето на приносот обично се анализира во однос на нивото на индексот на болеста и приносот постигнат во нетретирани експериметални површини, без да се земе предвид влијанието на другите елементи на животната средина. Оваа студија беше спроведена со цел да се одредат комбинираните ефекти на биотските фактори (индекси на болеста) и абиотските фактори (климатски елементи и ефикасност на фунгициди) врз постиганиот принос кај сорти зимски пченица. Беа поставени ескпериметални површини под инокулум на преовладувачки природно присутни економски патогени на пченицата во периодот 2006-2017 година. Во студијата беа користени модели - сорти Barbee и Durumko за кои се знае дека имаат различни степени на подложност на патогени од пченица. Општа линеарна модел функција на Minitab 17 (пробна верзија) беше користена за сите анализи. Беше утврдено дека загубата на родот во нетретирани експериментални парцели беше значително под влијание на комбинираните ефекти на повеќе болести и климатски елементи. Покрај тоа, беше утврдено дека односот помеѓу ефикасноста на фунгицидот и постиганатиот принос не е јасен и дека треба да се анализира во однос на комбинираните ефекти на биотските и абиотските фактори.

Клучни зборови: *пченица, ефинаксно на фунгицид, принос на зрно, житни 'рѓи, пепелница, Septoriatriticiblotch, абиотски фактори*