*Pak. J. Bot.*, 43(3): 2125-2138, 2010.

# EFFECT OF AGRONOMIC PRACTICES ON THE DEVELOPMENT OF *SEPTORIA* LEAF BLOTCH AND ITS SUBSEQUENT EFFECT ON GROWTH AND YIELD COMPONENTS OF WHEAT

**M. ANSAR[1], NASIR MAHMOOD CHEEMA[*] AND M. H. LEITCH[2]**

*[1]Pir Mehr Ali Shah Arid Agriculture University, Rawalpindi*
*[2]University of Wales, Aberystwyth, UK*
*[*]E.mail: cheemanm_786@yahoo.com*

**Abstract**

The agronomic practices such as nitrogen fertilizer and population density affect the plant vegetation pattern and cnopy structure and change the pathogenic activities through the microclimate variability generated as a result of these practices and thus modify the disease development. A study was carried out in the field to investigate the effect of three nitrogen rates (0, 150 and 300 kg $ha^{-1}$) and three tiller densities (600, 120 and 30 tillers $m^{-2}$) on the development of *Septoria tritici* on wheat variety Pastiche. The results revealed that nitrogen application increased the severity of *S. tritici* up to 150 kg $ha^{-1}$ but doubling this rate produced a slight reduction in the disease level on all leaves assessed both at growth stage (GS) 55 and GS 70 however, the difference was not significant. Increasing shoot density increased the development of *S. tritici* at GS 55which is attributed to a more favourable microclimate produced with in the leaf canopy at a higher tiller densities compared with produced at the lower tiller densities. However, a very small reduction was recorded at GS 70 at the highest density level when tiller density increased from 120 to 600 tiller $m^{-2}$. The grain yield progressively increased with the increase of both density and nitrogen levels.

## Introduction

The changing nature of agricultural inputs and climatic conditions can influence the occurrence and spread of the disease to a large extent. No agricultural system seems to be complete without the optimum plant population and nitrogen applications. These factors can change the morphology and physiology of the growing plant and influence the growth and yield of the plant either directly or by the disease development (Ansar *et al*., 1996; Engelhard, 1989). There has been a common observation that the use of large amounts of nitrogen causes a more dense canopy and higher shoot densities which favour *Septoria* epidemics. This effect may be due in part to changes in crop density and hence the microclimate (Jenkyn & Finney, 1981). There is also possibility that disease development is more associated with the tissue nitrogen contents of the host plant. So it was considered valued to see the impact of different tiller densities and nitrogen regimes on *S. tritici* which could be the result of either the tissue contents of the host plants or the microclimate generated as a result of different tillers densities. Canopy architecture, increased nutritional status and succulence of leaves associated with high nitrogen levels could also facilitate the pathogen attack (Huber, 1980). The present study was designed in view of the previous years glass house experiments where the micoclimate which is prerequist for disease development could not develop and produce results as under field conditions (Ansar *et al*., 2006). It was decided to undertake an experiment including both nitrogen and plant density variables under field conditions as both the variable influence the microclimate, tissue contents of the plant and disease development subsequently affecting the final yield and yield attributes of the crop. The study was undertaken in more

natural conditions where the incidence and damage caused depends entirely on the prevailing environmental conditions. The objective of this experiment was to assess disease development as it progressed on an individual plant basis and to quantify its subsequent effect on grain yield.

## Materials and Methods

Seeds of the winter wheat cultivar Riband were grown under field condtions. The fertiliser in the form of ammonium nitrate was applied as split application with 1/3 applied at GS 30 (tillering stage) and 2/3 at GS32 on 1st week of April. The herbicide methabenzthiazuron (Tribunil, Bayer) was applied in mid November while all other management practices were kept same for all the treatments. Site history of the soil in which the experiment was conducted, comprised of a four year grass ley. The crop was sown in the 1st week of October. Plot size was kept to a minimum of 1x1.2 m2 and each plot was surrounded on all four sides by an untreated discard at a sown shoot density of 600 tillers $m^{-2}$ in order to reduce cross over effects between neighbouring treatments. The treatments were arranged in a randomised complete block design with four replicates.

The treatments comprised of three nitrogen rates (0, 150, and 300 kg $ha^{-1}$) and three tiller densities (600, 120 and 30 tillers $m^{-2}$). The plant density treatments were imposed manually by maintaining the shoot density at requied distance. There were, one at a seeding rate (numerically 600 tillers $m^{-2}$), the second at 5 cm between shoots in each row (120 tillers $m^{-2}$) and the third at 20 cm between shoots in each row (30 tillers $m^{-2}$). The latter two densities were maintained by removing other shoots at ground level, a process which was repeated on three occasions during the growing season to suppress newly formed shoots. After thinning the crop to the required plant population, the plots were fertilised at the three nitrogen rates of 0, 150 and 300 kg $ha^{-1}$.

Ten tillers from each plot were tagged with red string, and these were assessed for disease development at monthly intervals. The ears of the marked plants were covered with protective bags at the start of grain filling stage to protect from bird damage. This measure was taken in response to the heavy bird damage experienced in the previous year's field experiment. The leaf symptoms of disease were scored on leaf area basis using a key devised by James (1971). All the disease data was transformed using arcsine transformation and were subjected to statistical analysis.

At maturity, the 10 marked tillers were harvested separately to measure the yield components in more detail. The ears were threshed using a bench thresher to separate the grains from the chaff. The remaining traces of the chaff were blown away with hair drier. The following measurements were recorded at crop maturity.

1. Plant height (cm)
2. Dry matter production (g)
3. Number of grains $m^{-2}$
4. Number of grains $ear^{-1}$
5. Mean individual grain weight (mg)
6. Harvest index (%)
7. Estimated yield (t $ha^{-1}$)

The chemical analysis of the stems and grains was undertaken to determine the tissue nitrogen content and nitrogen uptake. The whole plot was harvested manually to determine grain yield. The data recorded during the season were analysed using standard analysis of variance techniques.

## Results

**a. *Septoria tritici* infection:** In general, the disease intensity was found to be greater on the older leaves compared to later emerging leaves. The disease data recorded at GS55 showed that increasing the level of nitrogen from 0 to 150 kg $ha^{-1}$ N, increased the level of *S. tritici* on all three fully expanded leaves that were assessed. However, in all three leaves a further increase to 300 kg $ha^{-1}$ nitrogen resulted in less disease than at either of the lower nitrogen regimes i.e., 0 and 150 kg $ha^{-1}$.

The density treatments showed a progressive increase in disease development with increasing density levels, in all the three leaves. The percent increase in disease area amounted to 46.9% and 117.0% on the flag; 15.9% and 54.2% on the 2nd and 11.8% and 130.8% on the third fully expanded leaves by increasing tiller density from 30 to 120 and from 120 to 600 tillers $m^{-2}$ respectively at GS 55 in each leaf (Tables 7, 8 & 9).

A similar pattern of disease development was found at GS70 although levels were lower than would have been expected in an average growing season. The level of disease increased with the increase of nitrogen rate upto 150 kg $ha^{-1}$, but doubling the rate of nitrogen to 300 kg $ha^{-1}$ showed less disease than both the lower nitrogen regimes. Again, this trend was observed on all three top fully expanded leaves. Increasing density also resulted in higher disease upto 120 tillers $m^{-2}$ although a further increase in tiller density (600 $m^{-2}$) showed less disease than that recorded at 120 tillers $m^{-2}$, even less than the lowest density i.e., 30 tillers $m^{-2}$ (Tables 10, 11, 12).

### b. Yield and yield components

**Estimated yield:** Estimated yield is calculated from the yield components obtained from the experimental plot. The combined harvested yield can represent more accurately the yield obtained from the field experiments rather than the yield which is estimated from just 10 shoots. Secondly, the sub sample is usually taken from the inner rows while the plot yield also includes the border rows which yield differently than the rows within the plots. The data presented showed that with the increased rate of nitrogen application, the grain yield increased (Table 1). The application of nitrogen @ 150 kg $ha^{-1}$ increased yield by 18.7% compared with the untreated control. A further increase of only 4.2% was achieved by doubling the nitrogen application. The density treatment produced a larger effect on yield. The tiller density maintained at the level of 30 tillers $m^{-2}$ yielded least (1.27 t/ha) while the density of 120 tillers $m^{-2}$ produced an intermediate value (4.50 t $ha^{-1}$) and the highest grain yield (8.68 t $ha^{-1}$) was achieved from the tiller density of 600 $m^{-2}$. There is significant interaction between the shoot density and nitrogen rates which suggest that there is progressive increase in grain yield with the increase of nitrogen application at each density level except the lowest density (30 tilles $m^{-2}$) which resulted in lowest grain yield (1.18 t $ha^{-1}$) at 150 kg $ha^{-1}$ N application compared to untreated control (1.24 t $ha^{-1}$). The magnitude of first half N application is more than the additional half nitrogen application at each density level except the lowest one where opposite is true.

**Mean individual grain weight:** The effect of nitrogen on mean individual grain weight showed no difference in this experiment however, there was small increase as nitrogen rate increased from 0 to 150 kg $ha^{-1}$, but subsequently decreased as nitrogen application was increased from 150 to 300 kg $ha^{-1}$ but the differences are not accountable (Table 2). The percentage increase by 150 kg $ha^{-1}$ nitrogen was 3.4% and the subsequent reduction by doubling the dose was 1.3%. The density treatments showed that at the highest tiller density $m^{-2}$ the individual grain weight was lower than at the two lower densities, which were similar.

**Table 1. Effects of shoot density and nitrogen rates on grain yield (t ha$^{-1}$).**

| Nitrogen rates (kg ha$^{-1}$) | 600 tillers m$^{-2}$ | 120 tillers m$^{-2}$ | 30 tillers m$^{-2}$ | Means |
|---|---|---|---|---|
| 0 | 7.43 | 3.99 | 1.24 | 4.22 |
| 150 | 9.27 | 4.57 | 1.18 | 5.01 |
| 300 | 9.34 | 4.93 | 1.38 | 5.22 |
| SE | | 0.205** | | 0.149** |
| Mean | 8.68 | 4.50 | 1.27 | |
| SE (34 d.f.) | | 0.149** | | |

**Table 2. Effects of shoot density and nitrogen rates on mean individual grain weight (mg).**

| Nitrogen rates (kg ha$^{-1}$) | 600 tillers m$^{-2}$ | 120 tillers m$^{-2}$ | 30 tillers m$^{-2}$ | Means |
|---|---|---|---|---|
| 0 | 43.90 | 46.40 | 46.97 | 45.76 |
| 150 | 45.39 | 48.74 | 47.86 | 47.33 |
| 300 | 45.14 | 47.19 | 46.62 | 46.32 |
| SE | | 0.833NS | | 0.481NS |
| Mean | 44.81 | 47.44 | 47.15 | |
| SE (34 d.f.) | | 0.481** | | |

**Table 3. Effects of shoot density and nitrogen rates on number of grains ear$^{-1}$.**

| Nitrogen rates (kg ha$^{-1}$) | 600 tillers m$^{-2}$ | 120 tillers m$^{-2}$ | 30 tillers m$^{-2}$ | Means |
|---|---|---|---|---|
| 0 | 36.37 | 39.43 | 39.76 | 38.52 |
| 150 | 38.44 | 39.64 | 40.85 | 39.64 |
| 300 | 39.58 | 38.42 | 39.33 | 39.11 |
| SE | | 0.780NS | | 0.450NS |
| Mean | 38.13 | 39.16 | 39.98 | |
| SE (34 d.f.) | | 0.450** | | |

**Number of grains per ear:** The number of grains per ear was increased by 3.2% with the application of 150 kg N ha$^{-1}$, but was subsequently reduced by 1.4% when the nitrogen rate was increased to 300 kg ha$^{-1}$ (Table 3). The density treatment also showed that the higher the density, the lower the number of grains per ear partly due to the competition of available resources.

**Harvest index:** The harvest index increased with increased rate of nitrogen fertiliser (Table 4). The values recorded for the harvest index were 51.1, 52.0 and 53.2% for 0, 150 and 300 kg ha$^{-1}$ nitrogen application respectively. Density treatments suggest that with a decrease in density from 600 to 120 tillers m$^{-2}$, the harvest index increased from 48.4% to 55.1%, but with a further decrease in density i.e., from 120 to 30 tillers m$^{-2}$, a value of 52.9% was recorded. Fungicide application had little effect on the harvest index. The values recorded for harvest index with fungicide was 51.5% but without fungicide it was 52.7%.

**Grain weight m$^{-2}$:** The data regarding grain weight m$^{-2}$ from ten marked tillers is presented in Table 6 and shows that mean grain weight increased significantly with the application of nitrogen. Both nitrogen treatments produced higher grain weight than the

untreated control, but did not differ between themselves. The difference is small and statistically is not significant. The density treatments showed that plant density directly influenced the grain weight $m^{-2}$. The higher the tiller density, the greater the grain weight. The values recorded for grain weight were 91.16, 419.38, and 961.74 g from the ten tillers at densities of 30, 120 and 600 $m^{-2}$ respectively.

There is significant interaction between the density treatments and nitrogen rates which suggest that with the increased application of nitrogen grain weight $m^{-2}$ increased at each density level except at the lowest tiller density where the untreated control produced more grains $m^{-2}$ than the 150 kg N $ha^{-1}$ however, the magnitude of effect between the nitrogen applied treatments is low compared to the untreated control except at lowest tiller density.

**Plant height:** On average, plant height increased with increased the application of nitrogen (Table 8). The values noted for 0, 150 and 300 kg $ha^{-1}$ nitrogen were 71.8, 75.1 and 75.4 cm respectively. This suggests that the first 150 kg $ha^{-1}$ of nitrogen was more effectively utilised by the wheat plant than the second increment of 150 kg $ha^{-1}$ nitrogen. The density treatments showed that as density increased there was a progressive increase in plant height. The values recorded were 78.6, 74.4 and 69.2 cm for plants growing in tiller densities of 600, 120 and 30 $m^2$ respectively (Fig. 1).

**Tissue nitrogen contents and nitrogen uptake:** The density treatments also had a significant effect on the tissue nitrogen concentration in stems and grains. In general, as density level increased, the tissue nitrogen concentration decreased although the effect was greater in going from 30 to 120 tillers $m^{-2}$ than from 120 to 600 tillers $m^{-2}$. The highest nitrogen concentration was found in grains compared with the stems. In the case of the stem tissue nitrogen concentration, no difference was observed at the two higher tiller densities, but there was a 22% increase when tiller density decreased from 120 to 30 tiller $m^{-2}$ (Fig. 2). Increasing the nitrogen rate increased the nitrogen content of stems and grains (Figs. 2 & 3). The increase from the untreated control to 150 kg $ha^{-1}$ nitrogen was 43% in stems and 28% in grains while increasing the rate of nitrogen from 150 to 300 kg $ha^{-1}$ gave an increase of 23% in stems and 15% in grains.

The highest nitrogen uptake was by the grain, followed by stems, (Figs. 4 & 5). The increased rate of nitrogen application produced a progressive increase in nitrogen uptake in all components (stems, grains). By increasing nitrogen from 0 kg $ha^{-1}$ to 150 kg $ha^{-1}$, the increase was found to be 3.5% and 55.2% in stems and grains respectively. Similarly, with the further increase from 150 to 300 kg $ha^{-1}$ nitrogen application, the increase was found to be 2.6% and 22.2% in stems and grains respectively.

The density treatments affected nitrogen uptake both in stems and grains. The nitrogen uptake increased with increased tiller density. The values of stem nitrogen uptake were 2.77 g $m^{-2}$, 1.04 g $m^{-2}$ and 0.37 g $m^{-2}$ at 600, 120 and 30 tillers $m^{-2}$ respectively, while the values for grain nitrogen uptake were 14.38, 7.62 and 2.41g $m^{-2}$ (Fig. 4).

There was a significant interaction between nitrogen and density treatments which suggests that the response to nitrogen was greater at the two high plant densities than at the lower plant density (Fig. 5). No other treatment interaction was found to be statistically significant.

**Table 4. Effects of shoot density and nitrogen rates on harvest index.**

| Nitrogen rates (kg ha$^{-1}$) | 600 tillers m$^{-2}$ | 120 tillers m$^{-2}$ | 30 tillers m$^{-2}$ | Means |
|---|---|---|---|---|
| 0 | 45.86 | 52.72 | 54.79 | 51.12 |
| 150 | 49.78 | 56.26 | 49.93 | 51.99 |
| 300 | 49.45 | 56.36 | 53.91 | 53.24 |
| SE | | 1.889NS | | 1.090NS |
| Mean | 48.36 | 55.11 | 52.87 | |
| SE (34 d.f.) | | 1.090** | | |

**Table 5. Effects of shoot density and nitrogen rates on number of ears m$^{-2}$.**

| Nitrogen rates (kg ha$^{-1}$) | 600 tillers m$^{-2}$ | 120 tillers m$^{-2}$ | 30 tillers m$^{-2}$ | Means |
|---|---|---|---|---|
| 0 | 761.93 | 398.90 | 124.61 | 428.48 |
| 150 | 946.04 | 456.93 | 119.89 | 507.62 |
| 300 | 955.14 | 495.11 | 138.96 | 529.74 |
| SE | | 25.000* | | 14.433** |
| Mean | 887.70 | 450.32 | 127.82 | |
| SE (34 d.f.) | | 14.43** | | |

**Table 6. Effects of shoot density and nitrogen rates on grain weight (g m$^{-2}$) at harvest.**

| Nitrogen rates (kg ha$^{-1}$) | 600 tillers m$^{-2}$ | 120 tillers m$^{-2}$ | 30 tillers m$^{-2}$ | Means |
|---|---|---|---|---|
| 0 | 631.29 | 338.89 | 105.48 | 358.55 |
| 150 | 787.55 | 388.12 | 100.65 | 425.44 |
| 300 | 793.50 | 419.42 | 116.97 | 443.30 |
| SE | | 21.865** | | 12.624** |
| Mean | 737.44 | 382.14 | 107.70 | |
| SE | | 12.624** | | |

**Table 7. Effects of shoot density and nitrogen rates on *Septoria tritici* development on first fully expanded leaf at GS 55.**

| Nitrogen rates (kg ha$^{-1}$) | 600 tillers m$^{-2}$ | 120 tillers m$^{-2}$ | 30 tillers m$^{-2}$ | Means |
|---|---|---|---|---|
| 0 | 0.00(0.00) | 0.43(0.033) | 1.03(0.10) | 0.49(0.04) |
| 150 | 0.95(0.083) | 0.98(0.10) | 1.24(0.14) | 1.06(0.11) |
| 300 | 0.00(0.00) | 0.00(0.00) | 0.80(0.12) | 0.27(0.039) |
| SE | | 0.530NS | | 0.306NS |
| Mean | 0.32(0.03) | 0.47(0.04) | 1.02(0.12) | |
| SE | | 0.306NS | | |

**Table 8. Effects of shoot density and nitrogen rates on *Septoria tritici* development on second fully expanded leaf at GS 55.**

| Nitrogen rates (kg ha$^{-1}$) | 600 tillers m$^{-2}$ | 120 tillers m$^{-2}$ | 30 tillers m$^{-2}$ | Means |
|---|---|---|---|---|
| 0 | 1.05(0.20) | 1.70(0.30) | 3.58(1.20) | 2.11(0.57) |
| 150 | 2.32(0.33) | 2.38(0.57) | 5.64(2.07) | 3.45(0.990 |
| 300 | 0.60(0.07) | 0.52(0.050 | 2.46(0.63) | 1.19(0.25) |
| SE | | 0.1.671NS | | 0.965NS |
| Mean | 1.32(0.20) | 1.53(0.31) | 3.89(1.30) | |
| SE | | 0.965NS | | |

**Table 9. Effects of shoot density and nitrogen rates on *Septoria tritici* development on third fully expanded leaf at GS 55.**

| Nitrogen rates (kg ha$^{-1}$) | 600 tillers m$^{-2}$ | 120 tillers m$^{-2}$ | 30 tillers m$^{-2}$ | Means |
|---|---|---|---|---|
| 0 | 2.36(0.71) | 3.37(1.03) | 6.67(4.32) | 4.14(2.02) |
| 150 | 4.65(1.43) | 5.77(3.16) | 10.80(7.40) | 7.07(4.00) |
| 300 | 2.40(1.03) | 1.39(0.35) | 6.84(4.64) | 3.54(2.01) |
| SE | | 3.609NS | | 2.084NS |
| Mean | 3.14(1.06) | 3.51(1.51) | 8.10(5.45) | |
| SE | | 2.084NS | | |

**Table 10. Effects of shoot density and nitrogen rates on *Septoria tritici* development on first fully expanded leaf at GS 70.**

| Nitrogen rates (kg ha$^{-1}$) | 600 tillers m$^{-2}$ | 120 tillers m$^{-2}$ | 30 tillers m$^{-2}$ | Means |
|---|---|---|---|---|
| 0 | 0.21(0.01) | 1.03(0.07) | 0.60(0.03) | 0.62(0.040 |
| 150 | 0.82(0.07) | 1.33(0.08) | 1.58(0.16) | 1.25(0.10) |
| 300 | 0.73(0.05) | 0.60(0.03) | 0.60(0.03) | 0.65(0.04) |
| SE | | 0.402NS | | 0.232NS |
| Mean | 0.59(0.04) | 0.99(0.06) | 0.93(0.08) | |
| SE | | 0.232NS | | |

**Table 11. Effects of shoot density and nitrogen rates on *Septoria tritici* development on second fully expanded leaf at GS 70.**

| Nitrogen rates (kg ha$^{-1}$) | 600 tillers m$^{-2}$ | 120 tillers m$^{-2}$ | 30 tillers m$^{-2}$ | Means |
|---|---|---|---|---|
| 0 | 3.51(0.38) | 5.20(0.85) | 4.09(0.53) | 4.27(0.59) |
| 150 | 4.49(0.68) | 4.39(0.63) | 3.88(0.58) | 4.25(0.63) |
| 300 | 3.86(0.48) | 4.10(0.56) | 3.68(0.43) | 3.88(0.49) |
| SE | | 0.447NS | | 0.258NS |
| Mean | 3.96(0.52) | 4.56(0.68) | 3.88(0.51) | |
| SE | | 0.258NS | | |

**Table12. Effects of shoot density and nitrogen rates on *Septoria tritici* development on third fully expanded leaf at GS 70.**

| Nitrogen rates (kg ha$^{-1}$) | 600 tillers m$^{-2}$ | 120 tillers m$^{-2}$ | 30 tillers m$^{-2}$ | Means |
|---|---|---|---|---|
| 0 | 4.38(0.67) | 5.85(1.18) | 5.52(0.99) | 5.25(0.95) |
| 150 | 4.56(0.82) | 6.94(1.53) | 5.55(1.07) | 5.68(1.14) |
| 300 | 4.92(0.80) | 4.35(0.60) | 4.59(0.67) | 4.62(0.69) |
| SE | | 0.743NS | | 0.429NS |
| Mean | 4.62(0.76) | 5.71(1.10) | 5.22(0.91) | |
| SE | | 0.429NS | | |

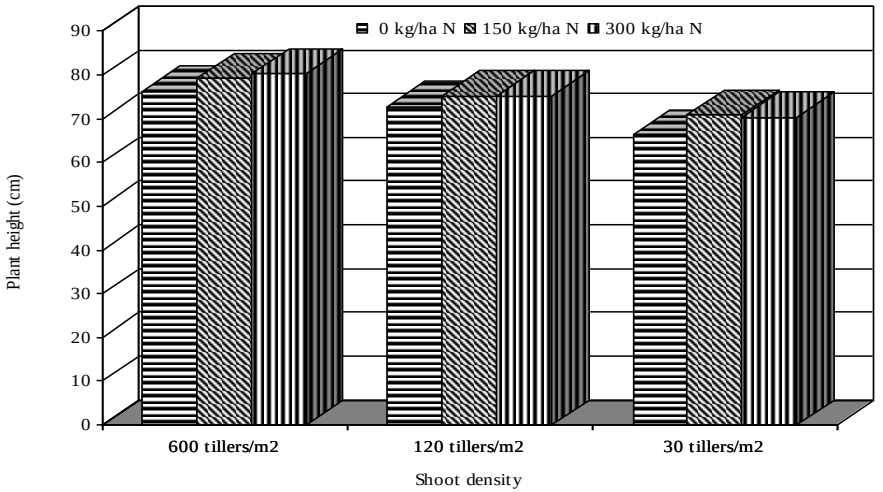


Fig. 1. Effect of nitrogen and shoot density on plant height of wheat variety CV. Riband at maturity.

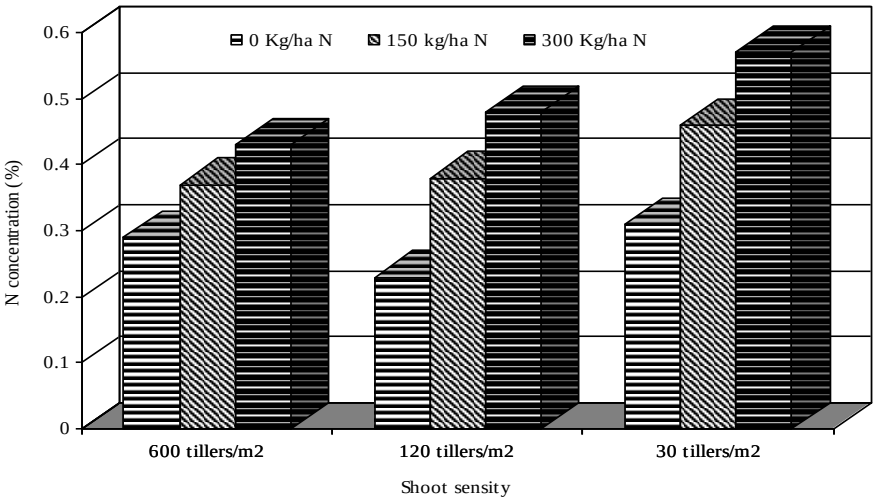


Fig. 2. Effect of nitrogen and shoot density on stem nitrogen concentration in wheat variety CV. Riband at maturity.

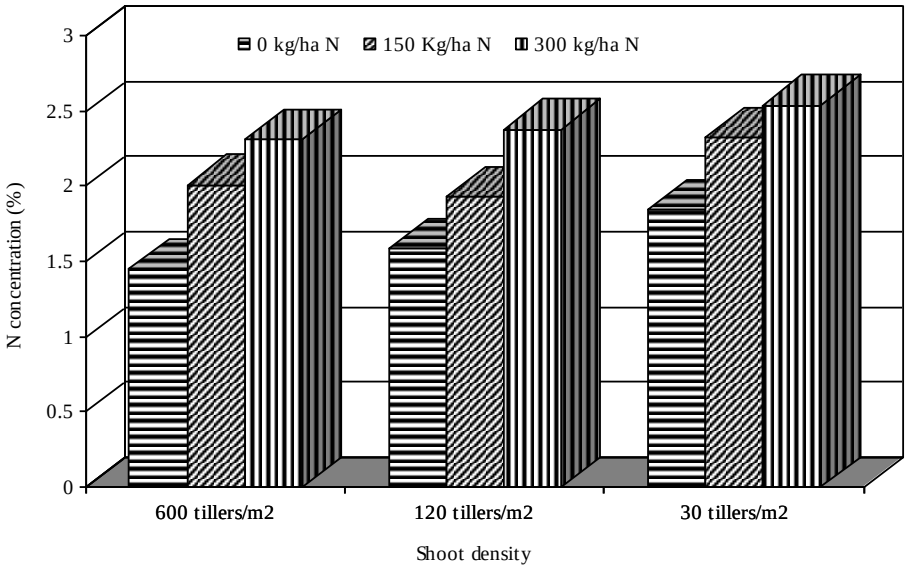


Fig. 3. Effect of nitrogen and shoot density on grain nitrogen concentration (%) in wheat variety CV. Riband at harvest.

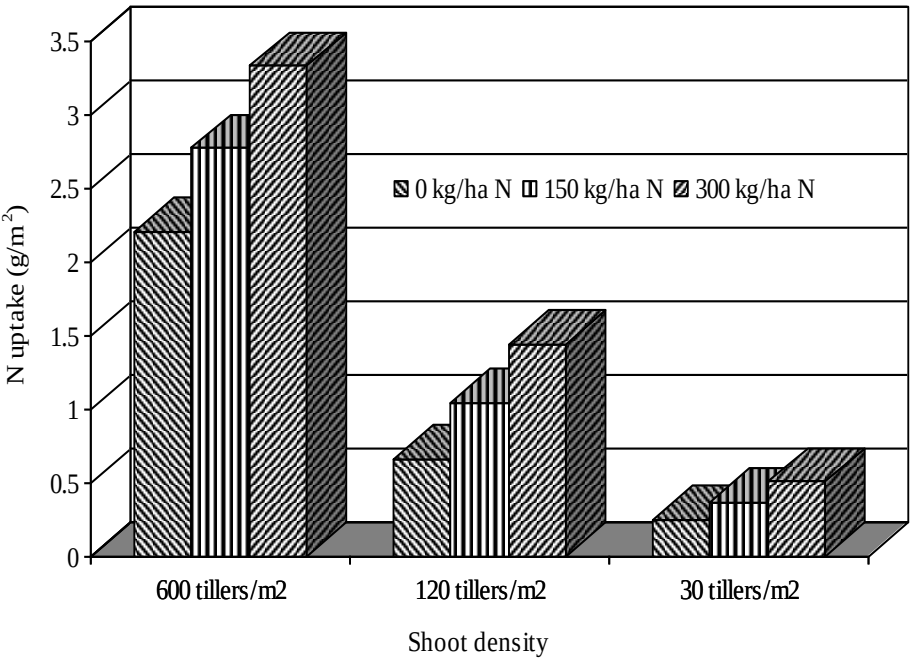


Fig. 4. Effect of nitrogen and shoot density on nitrogen uptake in stems in wheat variety CV. Riband at harvest.

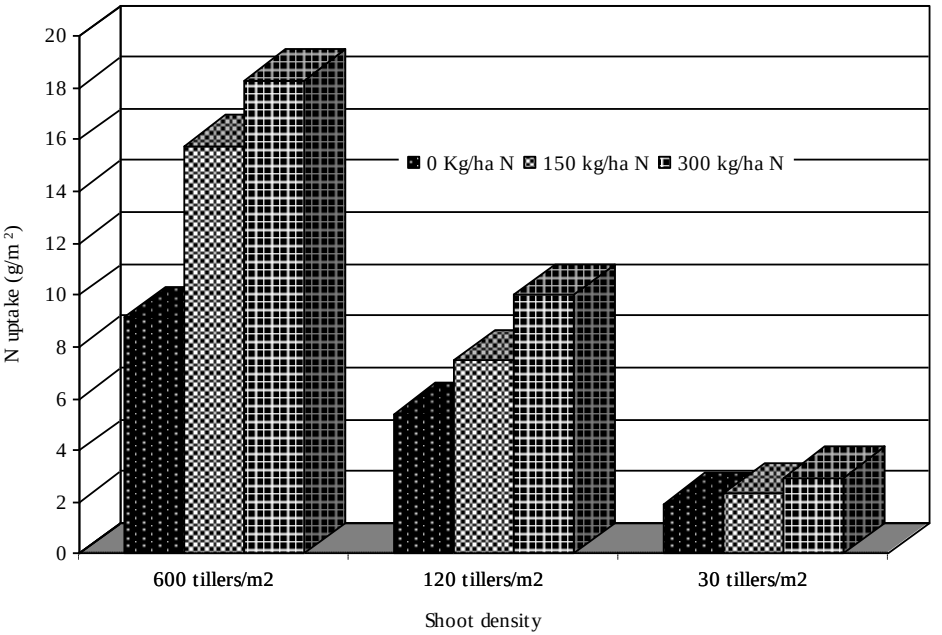


Fig. 5. Effect of nitrogen and shoot density on nitrogen uptake in grain in wheat variety CV. Riband at harvest.

## Discussion

**a. *S. tritici* infection:** The growing season was characterised by drought conditions which were not conducive to the development of *S. tritici* during grain filling. Generally, the disease symptoms progress up the plant with time, there being a greater severity of disease on the lower leaves. This was more prominent in the conditions that prevailed during the summer months where low rainfall limited the spread of disease to the upper levels of the canopy. There are several possible reasons for the greater level of disease on older leaves. Firstly, the lower leaves of the plant are close to the source of inoculum and spores of the pathogen more readily infect the older leaves than the younger ones. Secondly, as the older leaves are closer to the soil surface, there may be a more favourable microclimate generated by evaporation from the soil surface. Thirdly, there is the possibility that the leaves in the lower layer may retain the moisture and water droplets (rain, dew) for longer periods of time, as they are shaded and less exposed to air movement or direct sun. This again would produce a microclimate more conducive to disease development. Finally, the older leaves are exposed to inoculum earlier than the younger leaves, allowing more time for inoculum to develop and spread.

The disease, recorded on two occasions during the season at GS 55 and GS 70 on the top three fully expanded leaves, showed that there was no significant effect of nitrogen and density treatments on disease development. On both occasions, on all the leaves scored however, the disease incidence increased with the nitrogen application @150 kg $ha^{-1}$, further increase in nitrogen from 150 to 300 kg $ha^{-1}$, however, caused a reduction in disease development on both occasions. A similar trend was observed on all three fully expanded leaves. The initial increase in disease may occur in response to the physical and

chemical nature of leaves produced in situations of high nitrogen availability. Larger, greener leaves with a higher nitrogen concentration may be more susceptibility to *S. tritici* infection. Subsequent reduction as nitrogen rate increased from 150 to 300 kg/ha, as it was also seen in the yield components (mean individual grain weight and number of grains $ear^{-1}$) reduced incidence of disease to a lower level than that recorded at zero nitrogen application. It remains unclear, why disease is subsequently reduced at the higher rate of nitrogen availability. This question needs further investigations to properly answer, however, it has been suggested (Zadok, 1993) that each pathogen has its own host level of nitrogen concentration for optimum spread and development in the tissue which could enhance the disease susceptibility by creating a microclimate that would favour the growth of that particular pathogen. Possibly the 300 kg N $ha^{-1}$ created toxicity or such a defence mechanism in the leaves that restricted *S. tritici* development. It is unlikely to have any indirect effect of nitrogen on plant or canopy architecture, since populations were strictly maintained at given densities, although plant height was significantly increased with increased nitrogen application and less inoculum may have been dispersed in the taller plant stands. Differences in plant heights only amounted to 4.59 cm and it is unlikely that such a small difference would cause such a profused effect on disease development. Eyal & Ziv (1974) stated that on taller cultivars the disease progressed slower and did not reach the upper plant portions to the same extent as in the dward cultivars. The results of this work suggest that application of nitrogen to a certain level favours the development of *S. tritici,* however, beyond this level suppression of the disease occurs.

The effects of density indicated that as density increased disease increased progressively at GS55, but only up to the intermediate density at GS70. The average of the three leaves assessed was found to be 1.59, 1.84 and 4.34% at tiller densities of 30, 120 and 600 tillers $m^{-2}$ at GS55. This indicates that disease intensity increased 15.1% when the tiller density increased from 30 to 120 $m^{-2}$ and 135.9% when further density increased from 120 to 600 tillers $m^{-2}$. The greater disease development at higher density may be due to a more favourable microclimate produced within the leaf canopy at higher tiller densities compared with that produced at the lower tiller densities. Tompkins *et al*., (1993), Seligman *et al*., (1983) and Burrage, (1976) are of the opinion that canopy temperature could have been influenced by differences in rates of transpiration with in the various canopies. This seems to be producing higher RH which in turns has cooling effect in the canopy. The higher RH can also be associated with denser canopy by the reduced air movement. All these factors are conducive for the development of *S. tritici.* The reduction in disease at the higher density at GS70 is not consistent with this theory. However, it is possible that other factors had a bigger influence on disease development at this later stage of growth. For example, the drought spell may have reduced the soil moisture at the higher density more at this stage, providing conditions less favourable for disease development. Gaunt (1980) stated that excessive vegetative growth is a disadvantage because dense canopies exhaust soil moisture more rapidly through transpiration, than less dense canopies, and as a consequence the photosynthetic rate and other physiological activities of the plants are adversely affected. The second probability could be that at the higher density (600 tillers $m^{-2}$) the leaf tissue nitrogen may not be at a level which is sufficient for optimal disease development. The lower level of infection at GS 70 may also have resulted from lower levels of (splash) dispersal in the denser canopy from the lower layers of leaves to the upper layers. Eyal (1981) also reported that in thin

stand inoculum moves better than in thick ones. Also, there was a significant increase in the plant height recorded at harvest which may also have contributed to reduced dispersal of inoculum to the upper leaves.

**b. Yield and yield components:** The study undertaken showed that the grain yield increased with the increase in nitrogen rate due to the greater availability of nutrients. The first application of nitrogen increased yield four times more than that obtained by subsequently doubling the nitrogen dose. The reasons why the second 150 kg $ha^{-1}$ of nitrogen was not as beneficial as the first 150 kg $ha^{-1}$ may be that the soil medium is initially deficient in nitrogen. This is partially corrected by the first 150 kg $ha^{-1}$ where a large response is obtained. Additional nitrogen is utilised less effectively as there is less deficiency.

This is well explained in the law of diminishing return. The reason for such a increase in grain yield can be justified by the law of diminishing return, the utility of the first application of nitrogen to fulfil their requirements is greater than the next application. By increasing the nitrogen, mean individual grain weight and number of grains $ear^{-1}$ increased and contributed toward the final grain yield. The biggest increase was brought by the number of ears $m^{-2}$ which is 18.48% while the mean individual grain weight and number of grains $ear^{-1}$ only contributed 3.4 and 3.3% respectively with the application of 150 kg $ha^{-1}$. The increase of nitrogen from 150 to 300 kg $ha^{-1}$ caused a small reduction of 1.1, 1.3 and 1.4% of grain weight $m^{-2}$, mean individual grain weight and number of grains $ear^{-1}$ respectively. The reduction of these yield components is perhaps due to the unfavourable effect of the higher nitrogen application in these particular environments. Also, the excessive vegetative growth may not fill the grains as at higher nitrogen rates and grains remain lighter in weight.

In the case of density treatments, the grain yield increased with the increase of tiller density although the yield components, mean individual grain weight and number of grains $ear^{-1}$ were significantly reduced with the increase of density level, while the grain weight $m^{-2}$ increased significantly. The increase in grain weight is due to the large difference in the number of tillers. The grain weight increased 360.1% when the tiller density increased from 30 to 120 tillers $m^{-2}$ and further increase from 120 to 600 tillers density $m^{-2}$ raised the grain weight 129.3% inspite of the fact that the mean individual grain weight and number of grains $ear^{-1}$ decreased though not significantly. There was a progressive reduction in mean individual grain weight with the increase of tiller density. The decrease was recorded as 0.86% and 5.24% when the tiller density increased from 30 to 120 and 120 to 600 tillers respectively. Similarly, progressive reduction in the number of grains per ear was observed (0.07% and 7.30%) when the tiller density increased from 30 to 120 and 120 to 600 tillers $m^{-2}$. The percentage of reduction both in mean individual grain weight and number of grains $ear^{-1}$ is very low at two lower densities compared to the highest tiller density which could be explained by the *S. tritici* infection at GS55 and the competition of resources within the ear at the higher tiller density. The reduction both in mean individual grain weight and grain number $ear^{-1}$ correspond to the increased disease intensity recorded (GS55), the percentage increase in *S. tritici* was found to be greater when the tiller density increased from 120 to 600 tillers $m^{-2}$. Many other workers (Hess & Shaner, 1987, Williams & Jones, 1972, Shipton, *et al.*, 1971 and Jenkins & Morgan, 1969) reported reduction in mean individual grain weight and kernel number per ear with increased *S. tritici* infection.

At harvest, chemical analysis of the grains and stems showed that nitrogen application significantly increased the nitrogen contents and uptake in all these three components. The nitrogen application increased progressively the concentration of nitrogen in stem and grains. The first (150 kg N $ha^{-1}$) application of nitrogen increased the nitrogen concentration by 42.9 and 28.2% in stem and grains compared with the untreated control while the higher application (300 kg N $ha^{-1}$) only increased it by 22.5 and 15.3% in stem and grains respectively, again showing that the first 150 kg $ha^{-1}$ nitrogen was more beneficial than the second 150 kg $ha^{-1}$ nitrogen.

## Conclusion

The general observations drawn from this experiment were that the severity of *S. tritici* increased with the increase of nitrogen rate up to 150 kg $ha^{-1}$ but further increase did not favour the disease development which could be attributed to the vigorous growth of the host tissues. The density treatment increased the *S. tritici* intensity progressively with the increase of density level however, on the second occasion the highest density did not show the expected difference. Possibly, less moisture was available for the development of disease due to the prevailing drought. The yield of grains was found to be increased with the increase of density and nitrogen rate, although the difference between the two higher nitrogen rates remained very small.

### References

Ansar, M., M.H. Leitch, P.D. Jenkins and N.J. Hayden. 1996. Effect of nitrogen fertilizer, crop density and development of *Septoria tritici* on compoment of growth and yield of winter wheat in UK. A paper presented at 5th international Wheat Conference held in Turkey from June 10-14 1996. pp. 270-272.

Ansar, M., Z.I. Ahmed, M. Ashraf and A. Riaz. 2006. Effect of sowing densities on Septoria leaf blotch development and its subsequent effects on yield compoments of wheat. *Pak. J. Phytopathol.*, 18(2): 329-335.

Burrage, S.W. 1976. Aerial microclimate around plant surfaces. In: *Microbiology of Aerial plant Surfaces*. (Eds.): Dickinson, C.H. & Preece, T.F. Academic Press, London, UK. pp. 173-98.

Engelhard, A.W. 1989. Historical highlights and prospects for the future. In: *Soilborne plant pathogens: Management of diseases with Macro- and Microelements*. pp. 9-17. APS press.

Eyal, Z. 1981. Integrated control of *Septoria* diseases of wheat. *Plant Disease*, 65, 763-768.

Eyal, Z. and O. Ziv. 1974. The relationship between epidemics of *Septoria leaf Blotch* and yield losses in spring wheat. *Journal of Phytopathology*, 64: 1385-1389.

Gaunt, R.F. 1980. Physiological basis of yield loss. In: *Crop loss assessment* (Eds.): P. S. Tenz & S.V. Krupa. pp. 98-111. University of Minnesota, Minneapolis.

Hess, D.E. and G. Shaner. 1987. Effect of moisture on *Septoria tritici blotch* development on wheat in the field. *Phytopathology*, 77: 220-226.

Huber, D.M. 1980. The role of nutrition in defense. In: *Plant Pathology-An advanced treatise*, Vol. 5, pp. 381-406. (Eds.): J.G. Horsefall & E.B. Cowling. Academic Press, N.Y.

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

Jenkins, J.E.E. and W.A. Morgan. 1969. The effect of *Septoria* diseases on the yield of winter wheat. *Plant Pathology*, 18: 152-156.

Jenkyn, J.F. and M.E. Finney. 1981. Fungicides, fertilizers and sowing date. In: *Strategies for the control of cereal diseases*. (Eds.): J. Jenkyn & R.T. Plumb) Oxford: Blackwell Scientific Publication Ltd. pp. 179-188.

Seligman, N.G., R.S. Loomis, J. Burke and A. Abshahi. 1983. Nitrogen nutrition and canopy temperature in field grown spring wheat. *Journal of Agriculture Society, Cambridge*, 101: 691-697.

Shipton, W.A., W.R.J. Boyd, A.A. Rosielle and B.I. Shearer. 1971. The common *Septoria* diseases of wheat. *Botanical Review*, 37: 231-262.

Shipton, W.A., W.R.J. Boyd, A.A. Rosielle and B.I. Shearer. 1971. The common *Septoria* diseases of wheat. *Botanical Review*, 37: 231-262.

Tompkins, D.K., D.B. Fowler and A.T. Wright. 1993. Influence of agronomic practices on canopy microclimate and *Septoria* development in No-till winter-wheat produced in the Parkland region of Saskatchewan. *Canadian Journal of Plant Sciences*, 73: 331-344.

William, J.R. and D.G. Jones. 1972. Epidemiology of *Septoria tritici* and *Septoria nodorum*. VI. Effect of time of initial infection on disease development and grain yield in spring wheat's. *Transactions of the British Mycological Society* 59: 273-283.

Zadoks, J.C. 1993. *Modern crop protection: development and perspectives Wageningen*. The Netherlands. pp. 165.

(Received for publication 10 December 2000)