INCREASING DENSITIES OF AVENA FATUA AND RUMEX DENTATUS REDUCE THE YIELD OF WHEAT UNDER FIELD CONDITIONS

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ABSTRACT
To estimate the yield losses due to interference of weeds is an important aspect for timely weed management. In view of this, two additive design experiments were conducted during rabi seasons and planted in November 2012 and subsequently repeated in 2013 to investigate the potential of various densities of Avena fatua and Rumex dentatus on the total biomass and yield of wheat in Dera Ismail Khan; the extreme southern district of Khyber Pakhtunkhwa, Pakistan. Randomized complete block design was used in both the experiments, by maintaining the density of A. fatua and R. dentatus in nine treatments (0, 5, 10, 15, 20, 25, 30, 35, 40 seeds m^{-2}) and three replications. The seed rate of wheat was 125 kg ha^{-1}. The results of each experiment indicated that the increasing densities of both A. fatua and R. dentatus severely decreased the wheat grain yield by 78 and 60 % and total dry matter yield by 80 and 74 % by A. fatua and R. dentatus, respectively as compared to control treatments. Furthermore, compared with lower densities of the weed species, the biomass of both A. fatua and R. dentatus was higher in the treatment having maximum density (40 plants m^{-2}). It can be concluded from these studies that the uncontrolled population of A. fatua and R. dentatus can cause severe reduction in wheat yield. Moreover, this study will facilitate the farmers and scientists to determine the threshold levels and competition indices of A. fatua and R. dentatus and other major weeds that cause yield reduction in wheat crop.
Keywords: Wheat crop, weeds, ecological design, threshold levels, grain yield

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INTRODUCTION

Wheat is the leading food grain crop in Pakistan (Mahmud et al., 2018) and occupies a major area in the country. As wheat can adapt to a wide range of climatic and soil conditions therefore wheat is grown in all parts of the country. Due to staple food, wheat is an important crop and thus plays an important role in national economy both in terms of production and consumption. Due to more area under cultivation and demand in the market, Pakistan is in the world's top 10 wheat producing countries (Hassan and Khan, 2006). It is a source of protein and major source of food supply in the country. It is the most important cereal and staple food crop of Pakistan sharing 13.7% to the value added in agriculture and 3.1% to GDP (Azam and Shafique, 2017). It is cultivated over an area of 9 million hectares with estimated production of 25.2 million metric tons (USDA, 2017). Likewise, the total cultivated area in Khyber Pakhtunkhwa is 0.76 million hectare with total production of 1383.4 thousand tons (SUPARCO, 2017). Wheat is popular in irrigated as well as in rainfed areas of the country. The relatively lower yield of wheat in Pakistan is attributed to improper irrigation and fertilizers (Nisar et al., 1996). Among other components of production technology, the weed infestation is common in rainfed and irrigated fields. Thus, the presence of weeds within a crop can adversely affect its yield in many ways and it has been estimated that globally yield reduction in wheat due to weeds is 13.1% (Siddiqui et al., 2010). To address the issue of fertilizer, the scientists are trying to formulate proper dose of fertilizer as per need of the crops in different ecological zones of the country (Hassan and Khan, 2006).

Weeds are unwanted plants that reduce straw yield by 13-38% and grain yield by 25-47 (Manandhar et al., 2007; Iqbal et al., 2018). Weeds compete for water, nutrients and light and reduces wheat grain yield therefore weed management is an important factor the needs attention. Wild oat (Avena fatua) reduced the wheat biomass and number of tillers (Balyan et al., 1991) and thus the presence of weeds increase the cost of production. Moreover, it has also been documented that A. fatua is a serious threat to wheat production in the local condition, causing severe yield losses if not controlled on proper time (Jack et al., 2017). Likewise, the increasing density and infestation of Rumex dentatus severely affect the yield and yield parameters of wheat crop due to its competition for resources and auto-toxicity during association with other crop (Waheed et al., 2017). Thus to estimate the decrease in yield of a crop, the competition models are important for better and timely weed management. Like fertilizer, the weed management is also an important factor that needs to be studied in relation to fertilizer application. Because a major portion of the fertilizers is utilized by the existing and associated weeds (Nisar et al., 1996). Farmers give importance to the fertilizer and irrigation in crop husbandry while weed management is considered non-economical.

Reddy et al. (2003) communicated that competition between crop and weeds is an established fact and thus more studies are suggested to get higher yields of crop. Competition between crop and weeds is considered an important aspect to avoid the yield losses. Because weeds competition can cause 83 % reduction in seed yield (Coxarelli and Tei, 1984). The magnitude of yield reduction of a crop is dependent on the duration of the presence of weeds with the respective crop (Anderson, 2000). Therefore the weed species, density and duration are important to be addressed. The control of weeds would increase the nitrogen use efficiency of the crop by decreasing removal of nutrients by associated weeds. Hans et al. (2003) reported that majority of the associated weeds consumed higher amount of nitrogen which ultimately affects the crop growth. Because the presence of weeds with the crop plants consume nitrogen which negatively affect the growth of crop plants. If fertilizer was applied without weed management than

addition of nitrogen enhance the growth of weeds also (Blackshaw et al., 2003). The reduction in yield of a crop is affected by several factors related to nitrogen application. Like time of application of nitrogen and the methods of nitrogen application (Evans et al., 2003), time of weed management is also important. Several researchers have documented that there was little effect of nitrogen application on the crop-weed competition (Blackshaw, 2005).

As weeds compete for water and nutrients applied to the crop, therefore it is needed to determine the proper stage of nutrients application and weed control practice, which may reduce the nutrient uptake by weeds. This way the models would help us the timely options for weed management strategies. Such prediction would reduce indiscriminate use of herbicides and labor, in addition to clean environment and food security. Because the competitive ability of different weeds under a given environment is always different. Therefore studies were conducted at Dera Ismail Khan district of Khyber Pakhtunkhwa, Pakistan to determine the negative effects of two major weeds on the biomass and yield of wheat.

MATERIALS AND METHODS

Field Experimental Site

In the present additive design field experiments, yield losses and competitive ability of two weeds were studied in the agro-ecological region of district Dera Ismail Khan during Rabi 2012-13 and subsequently repeated in 2013-14. Each year sowing was done during November. The district Dera Ismail Khan is located in the extreme southern part of Khyber Pakhtunkhwa province of Pakistan. Two separate experiments were conducted to evaluate the different densities of A. fatua and R. dentatus. For proper seed bed preparation and conducting the additive design experiments, the previously wheat cultivated on silty clay loam soil. All the recommended agronomic practices were adopted during the course of experiments. Before wheat and selected weeds sowing, seed beds were prepared as per standard agronomic practices prevailing in the area. The dose of nitrogen and phosphorus applied were at the rate of 120-90 NPK kg ha^{-1}.

Wheat and weed plants densities

When the height of plants reached to at least one foot in the experimental field, then the density of wheat and both weeds (Avena fatua and Rumex dentatus) were maintained according to the designed experiment through thinning. In each experiment, pure stands of wheat and weeds were obtained by thinning their dense population. An obvious, number of counted plants in each plot were maintained. By maintaining the proper density through thinning the inter plant competition were diminished and thus the nutrients and other useful resources were easily available to plants. All other weeds were removed manually throughout the crop season as per need.

Experimental design

During these studies two additive designed field experiments were conducted for the two selected weeds at Dera Ismail Khan; the extreme southern District of Khyber Pakhtunkhwa, Pakistan. As per our preliminary survey (data not given), these two weeds were important and major yield reducing winter weeds in wheat in Dera Ismail Khan. Therefore these weeds were selected for quantifying their competitive abilities. In both the experiments, the density of both A. fatua and R. dentatus were maintained in a randomized complete block design in nine treatments (0, 5, 10, 15, 20, 25, 30, 35 and 40 seeds m^{-2}) and three replications, while the seed rate of wheat seed was the same for all the treatments i.e. 125 kg ha^{-1}. The seeds of wheat were manually planted in a seedbed. The seeds of weeds were planted by mixing the seeds with wheat and sown in the treatments. For accuracy and desired and uniform density of crop and weeds, number of wheat seeds was calculated for each row.

Parameters studied

At maturity of the crop, several variables like total dry matter yield and grain yield of wheat and both the weeds (Avena fatua

and Rumex dentatus) were recorded and then converted into kg ha^{-1} by using the formula as given by Norman et al. (1965).

Grain yield of wheat (ha^{-1}) =

$$\frac{X \times 10000\ m^2}{\text{Row length} \times \text{Row - Row distence} \times \text{No. of Rows harvested}}$$

Where X= Grain yield ($plot^{-1}$)

Statistical analysis

Data collected were statistically analyzed by using Statistix 8.1, and LSD test was used for mean separation among the treatment means. Data were also subjected to Regression Analysis to establish the relationship. Trend lines show the average of two years for wheat, A. fatua and R. dentatus.

RESULTS

Grains yield of wheat

The grain yield of wheat recorded in different treatments with different densities of Avena fatua is predicted in (Fig. 1). The effect of increasing densities of A. fatua severely affect the grain yield of wheat in the treatment having 40 seeds m^{-2}, therefore, the higher yield of wheat (4663 kg ha^{-1}) was observed in the plots having 0 A. fatua seeds m^{-2} while the minimum yield of 1140 kg ha^{-1} was found in the treatment comprised of 40 A. fatua seeds m^{-2}. This was almost 78 % decrease in grain yield of wheat as compared to control (Fig. 2). The remaining treatments infested with higher densities of A. fatua shows significantly ($P \leq 0.05$) lower yield of wheat grains in comparison with the treatments having lower densities of A. fatua. In some treatments although the density of A. fatua was higher but there was no significant difference in grain yield compared to the treatments infested with higher density of A. fatua. Likewise, the minimum grain yield of wheat (1115 kg ha^{-1}) was observed in the treatments with 40 Rumex dentatus plants m^{-2}. This shows a 60 % decrease in grain yield of wheat (Fig. 2, $P \leq 0.05$)) as compared to the treatments having R. dentatus density of 0 seeds m^{-2} with wheat grain yield of 4790 kg ha^{-1}. In some treatments the increasing density of R. dentatus did not affect the grain yield of wheat and no significant difference was recorded. This was probability due to better tillering of wheat that suppressed the R. dentatus at initial stage of the growth. Overall Fig. 1 shows that the increasing densities of both A. fatua and R. dentatus are causing severe yield losses to wheat grain yield.

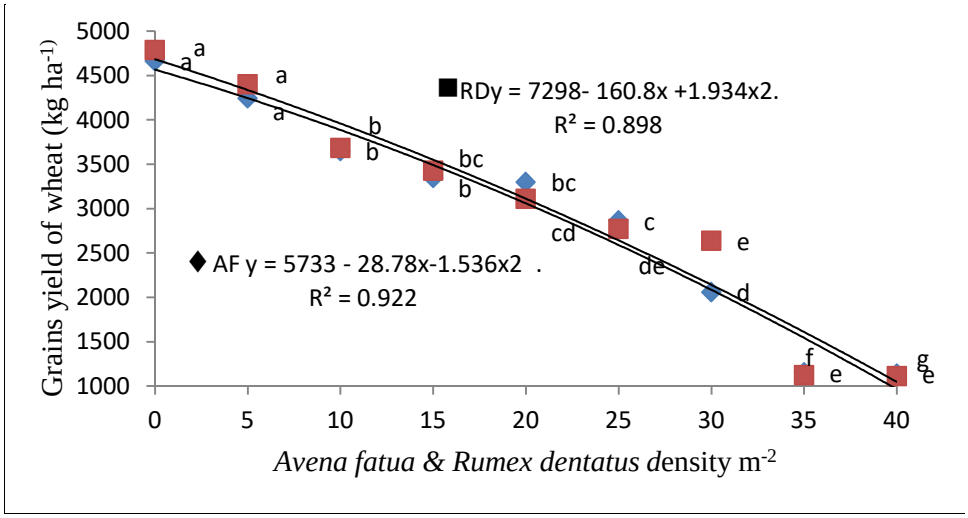

Figure 1. Wheat grain yield with various densities of A. fatua and R. dentatus

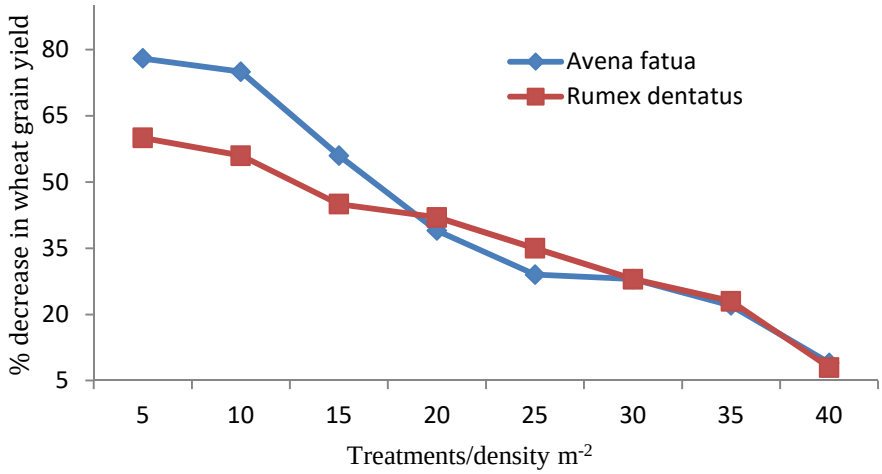

Figure 2. Percent yield reduction of wheat with various densities of A. fatua and R. dentatus

Dry biomass of wheat

The total dry matter (TDM) yield of wheat in the presence of different densities of Avena fatua and Rumex dentatus is given in Figure 3. It is obvious from the data that initially the treatments with lower density of A. fatua, there is higher TDM of wheat (12907 kg ha^{-1}). But on the other hand when the density is increased and reached upto 40 seeds of A. fatua m^{-2}, there is a significant ($P \leq 0.05$) 80 % decrease in wheat TDM yield (2627 kg ha^{-1}) (Fig. 4). Some of the treatments infested with different densities of A. fatua did not show a significant difference in decreasing the TDM yield of wheat. Similarly, the effect of different densities of R. dentatus on the TDM yield of wheat is also given in the same Fig. 3. The maximum TDM yield of wheat (12917 kg ha^{-1}) was recorded in the treatments provided with lower seeds (0 seeds m^{-2}) of R. dentatus while in contrast the minimum TDM yield of wheat (3423 kg ha^{-1}) was recorded in the treatment supplied with higher density (40 seeds m^{-2}) of R. dentatus, which shows about 74 % decrease (Fig. 4) in comparison with the control. Overall, Fig. 3 indicates that the infestation of high densities of both A. fatua and R. dentatus is decreasing the TDM yield of wheat in the field.

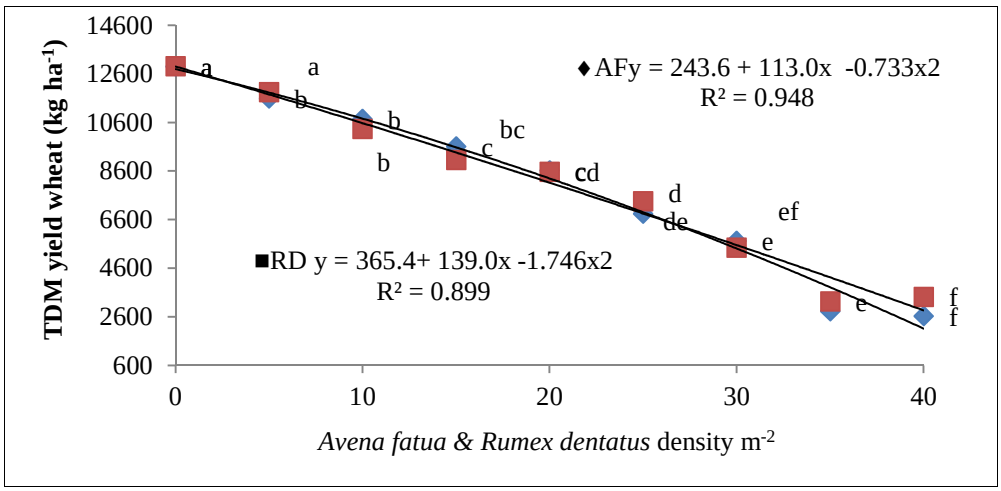

Figure 3. Dry matter of A. fatua and R. dentatus.

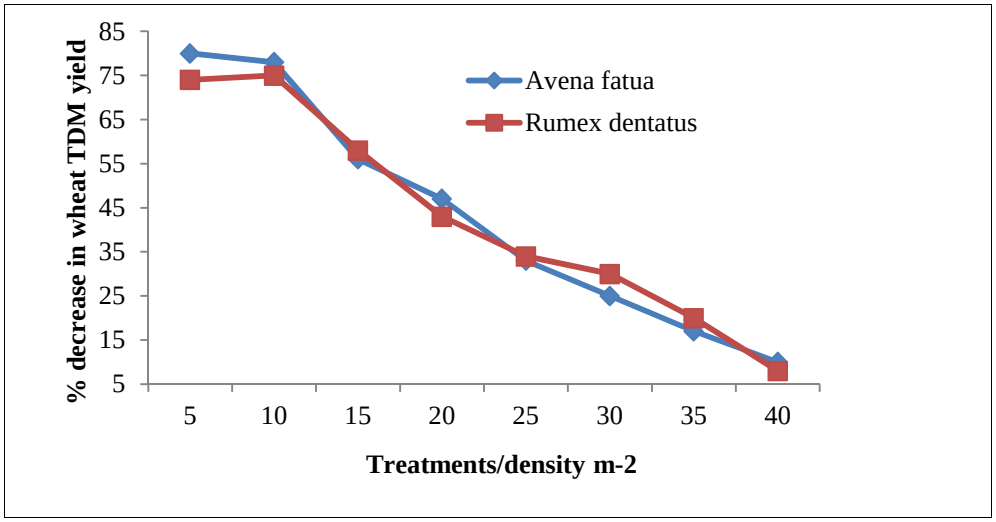

Figure 4. Percent decrease in dry biomass of wheat with various densities of A. fatua and R. dentatus

Dry biomass of A. fatua and R. dentatus

The TDM yield of both Avena fatua and Rumex dentatus is summarized in Fig. 5. The statistical analysed data for TDM of A. fatua applied in different densities in combination with wheat seeds is different in different treatments. Compared with control (0 A. fatua seeds m^{-2}), the maximum as well as significant ($P \leq 0.05$) TDM yield of A. fatua (3886 kg ha^{-1}) was noted in the treatments where it was applied in high density (40 seeds m^{-2}). In the same way, TDM yield of R. dentatus also showed a similar trend to the results of A. fatua. It is clear from the figure that the treatments with higher density of R. dentatus (40 seeds m^{-2}) showed maximum TDM yield of 12917 kg ha^{-1} as compared to the treatments provided with minimum density of R. dentatus (0 seeds m^{-2}). In general, the results of both A. fatua and R. dentatus (Fig. 5) show that its TDM yield is increasing with increasing density.

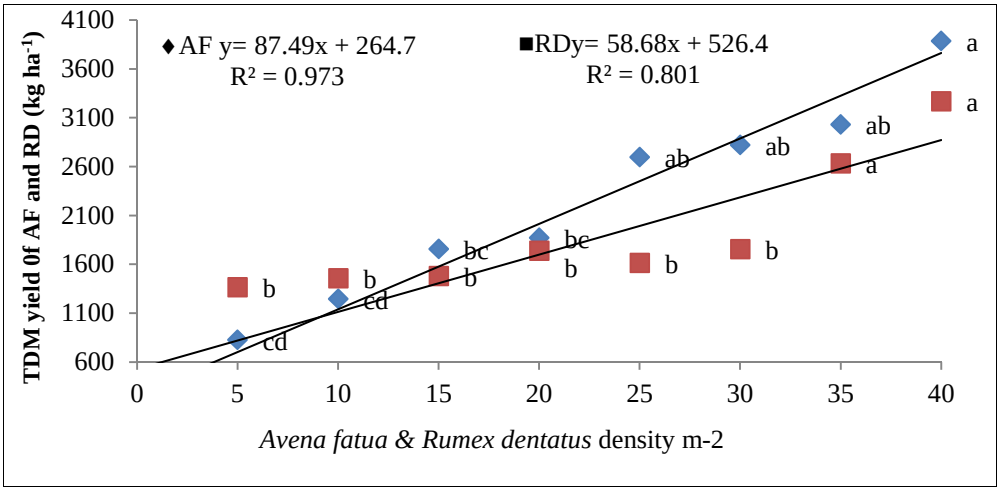

Fig. 5. Total dry matter yield of Avena fatua and Rumex dentatus.

DISCUSSION

In the months of October-November 2012-13, two additive design experiments were conducted at district D.I. Khan to decipher the competition of various populations of A. fatua and R. crispus ranging from 0-40 plants per square meter on dry biomass and wheat yield by using the newly released variety "Siren". Our results confirmed that both the weeds were highly competitive with wheat crop and reduced the grain yield and total dry matter yield of wheat in the agro-climatic conditions of D.I. Khan. The reduction in yield parameters of wheat due to the different densities of both A. fatua and R. dentatus may be ascribed to the information that during competition weeds may compete for some important factors like light, nutrients, space and water for their survival (Chandramohan et al., 2002).

In the current study, the effect of both weeds on wheat grain and dry matter yield was variable. The effect of R. dentatus on yield losses was higher than A. fatua but generally the effect of both weeds in competition caused 10-80 % reduction in wheat yield. The maximum wheat yield losses of one weed than the other might be due to the genotypic variation between weeds and crops (Javaid et al., 2007). Some studies have also documented that weeds and cereals compete for environmental resources mainly due to the physiological and morphological traits of plants (Didon, 2002). Furthermore, the canopy structure and plant height also affect the competitive ability of wheat plants (Korres and Froud-Williams 2002). Likewise, the allelopathic potential of wheat and their tillering capacity have also been confirmed to confer greater competitive ability in wheat crop (Korres and Froud-Williams, 2002). In the present study, compared to A. fatua the effects of R. dentatus were more effective against vegetative growth and grain yield (about 80% reduction) because of the rapid and luxurious growth of this weed in wheat crop and resulting competition for water, nutrients and light (Waddington & Bittman, 1984). In addition few researchers have reported that this weed also shows some allelopathic nature that may release some volatile alleopathic chemicals (Oleszek, 1987) and some quantities of water-soluble phytotoxins, sulphur and glucosinolates that inhibit the grain yield of wheat (Mayton et al., 1996).

The increasing densities of both A. fatua and R. dentatus severely affected the total dry matter and grain yield of wheat. One of these is narrow leaf while another one is broad leaf weed and both have rapid growth and some time attain more height than wheat crop and exhibit more competition for minerals, water, light and space and finally causing severe damage to the existing crop. The decrease in the total dry matter and grain yield of wheat may also be due to some allelopathic effects of both of these weeds during growth and competition (Namvar et al., 2009). Because the differentiation between allelopathy and competition is difficult under field conditions. In addition, it has also been documented that competition among the mixture of wheat, A. fatua and R. dentatus is considered a major issues for lower yield of the crop. Because the selection of cultivar, populations, and the interactions of the existing species are important. As both these weeds are major weeds of the area and the seed production of these weeds is also higher. Therefore keeping in view the competitive ability of these weeds, management of the weeds in wheat is suggested at early stages of the wheat crop to avoid grain yield losses.

CONCLUSION

The current study concludes that the increasing densities of both Avena fatua and Rumex dentatus are causing severe grain and total dry matter yield losses to wheat crop. This study will also provide an indication to the farmers and scientists to estimate the crop yield losses and threshold levels even from the presence of low densities of weeds. Likewise, this study will help the farmers and scientists to evaluate the competition indices of A. fatua and R. dentatus and other major

weeds in their crops by using ecological designs.

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