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Rye confers high anther extrusion to bread wheat via triticale x wheat crosses

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Abstract
Man made cereal, triticale, aims to combine desirable traits of wheat and rye in a single crop species. Outcross promoting floral traits from rye such as anther size and extrusion are relevant for development of fertility restorers for hybrid wheat programme. A large set of germplasm lines derived from triticale x wheat crosses underwent preliminary characterization in a previous study (Yousef, 2015). The initial cross involved improved triticale variety TL 2908, and wheat variety Chinese Spring with Ph suppressor genes (CSS). This was followed by a backcross with CSS and further backcrosses with improved wheat variety PBW 343. The huge improvement for anther extrusion was obtained in PBW343 which otherwise is shy floret opener.

Keywords: Triticale, outcrossing, wheat, *Secale cereale*, anther extrusion

Introduction
Wheat (*Triticum aestivum*) is the most important winter cereal in India contributing substantially to the national food security. Globally it provides more than 20% of the calories as well as 20% of the protein consumed by the human population. Historically, India has made great progress in wheat productivity followed by several significant advances fostered by various genetic interventions. Past decade has witnessed an enhancement of about 5 million tonnes in annual wheat production of the country despite area remaining the same. This trend not only needs to be sustained but accelerated in light of burgeoning population and increasing per capita consumption. The task has been made harder by depleting natural resources and climate change. The knowledge about the variability for various floral and yield traits is needed for their effective utilization in wheat improvement programmes. Development of hybrids is an alternative approach to get quantum jump in wheat production. One of the major difficulties in the commercial production of hybrid seed is the poor seed set on the male sterile lines by natural cross pollination (Porter and Atkins 1963; Kharde *et al.* 1967) [18]. Floral parts of wheat will be important for efficient production of hybrid seed. Wheat flowers are composed of spikelets which are made up of bract-like organs, glumes, and florets. The lemma and palea envelop the male and female reproductive organs. At anthesis, opens the floret and exposes the anthers and pistil for pollination, a state called chasmo gamy, floral structure anthesis and anther dehiscence patterns in wheat make this crop strictly autogamous (Percival 1921; De Vries 1971) [17]. For hybrid development, adequate cross pollination attributes are the necessity. The occurrence of outcrossing in wheat and the tendency for some cultivars to outcross more than others was well established. Important floral traits that influence outcrossing in wheat are stigma size, anther size, anther extrusion, pollen number and pollen viability. Wilson (1968) [19] Suggested that varieties with good anther characters be used as pollinators and those with open glumes and protruding stigma as female parents for good open pollination.Anther extrusion has been observed from 14.1 to 93.0% (Joppa *et al.* 1968; Singh and Joshi 2003) [10]. The wheat improvement response to hybrid development needs a broad germplasm base. Among the major crops, wheat has a relatively narrow genetic base owing to its evolutionary history. Ideally both male and female parental plants for hybridseed production would possess open flowering spikelets and the following desirable traits to achieve cross-pollination. Large lodicules, a soft lemma, and pale a in well-spaced spikelets along long spikes, would also enable each floret to open widely. The male ideotype plant would be tall with long extruded anthers producing large quantities of long-life pollen. In comparison, the female ideotype would be a shorter plant with multiple chasmogamous florets to maximize pollen reception. Stigmatic hairs would be long, fully extruded and receptive for extended periods.

The introduction of genetic variation from related species thus, presents an important avenue for wheat improvement. The wild progenitor species can be an important source. Among the cultivated related species *Secale cereale*, commonly known as rye can be of great value for wheat improvement on account of its considerable genetic distance from wheat. Rye can store fertility because it has large anther size, higher anther extrusion and more pollen load. These desirable floral traits may incorporate into wheat, via triticale x wheat crosses. Farther Selection of floral traits those enhance magnitude of out crossing, such as duration of flower opening, greater anther extrusion, large anther size, high pollen load and more receptive stigma etc.The amount of seed set depends largely on the extent of pollen grains shed by the pollinator (Wilson, 1968) [19]. This can prove restrictive for improvement of productivity and also makes wheat increasingly vulnerable to biological and environmental stresses. While it is a complex procedure, this is an achievable target, as our understanding of the control of floral architecture has greatly improved over the past few years.

Triticale not only possesses greater tolerance to common wheat diseases but is also high in essential amino acids, which makes it more nutritionally valuable than wheat (Horlein and Valentine 1995) [8]. An alternate course of action for utilization of rye genes involves use of, improved triticale as a bridging species for gene transfer to bread wheat. In wheat, this hurdle is removed by inducing homoeologous pairing. Apart from *Ph* gene knockouts, stocks with *Ph* suppressor genes from *Aegilops speltoides* (Chen *et al.* 1994) [2] can be used for this.

In the context of the wheat breeding programme at PAU, there are several traits which can be sourced from triticale. Owing to rapid evolution of stripe rust races, new sources of resistance are urgently needed. Karnal bunt is another important disease for which triticale can serve as a resistance donor. Further, outcross promoting floral traits from rye such as anther size and extrusion are relevant for development of fertility restorers for hybrid wheat programme. Intensive agriculture has led to large scale micronutrient deficiencies and rye chromosomes are known to confer tolerance in triticale. The trait seems to be under simple genetic control with good prospects of transfer to wheat.

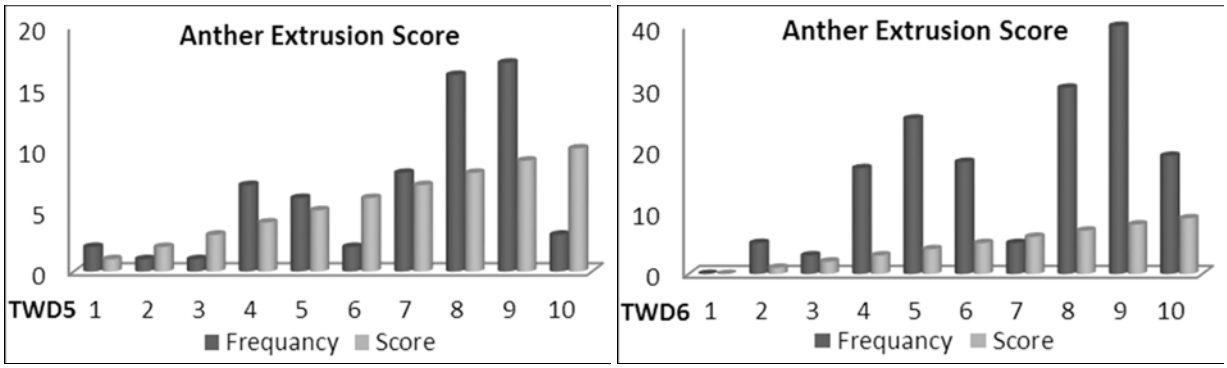
Material and Methods

A large set of germplasm lines derived from triticale x wheat crosses underwent preliminary characterization in a previous study (Yousef, 2015). The initial cross involved improved triticale variety TL 2908, and wheat variety Chinese Spring with *Ph* suppressor genes (CSS). This was followed by a backcross with CSS and further backcrosses with improved wheat variety PBW 343. The BC_2F_7 generations were studied with respect to large number of traits anther extrusion being one of them. Plant material used for the study consisted of two sets of lines derived from triticale x wheat crosses. The first set consisted of 60 lines along with parents and second set consisted of 165 lines along with parents. The first set (TWD5) was picked from a larger set of derivatives on basis of resistance to stripe rust and the second set (TWD6) comprised of lines derived from a larger set on preliminary morphological indication of rye introgression.

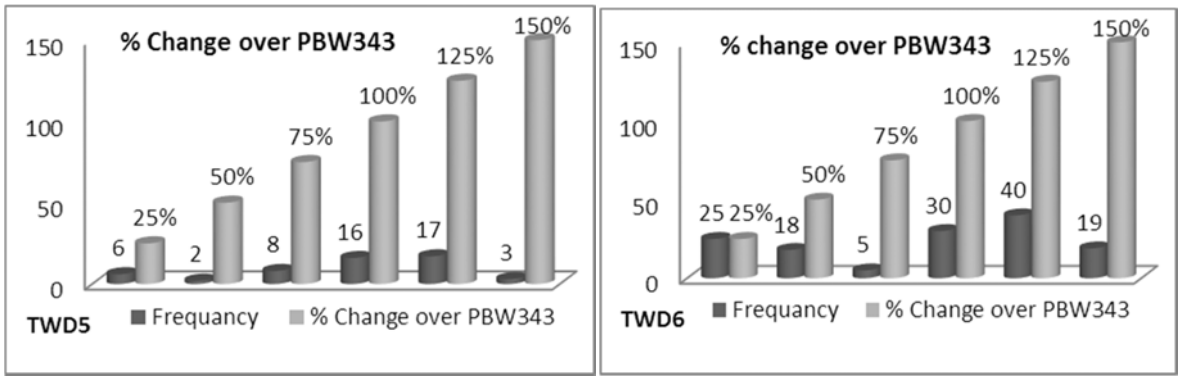
Anther extrusion was recorded visually in the plots at the time of an thesis. Ears which had shown an thesis over the previous 5-6 days were considered. Five to ten ears showing maximum number of anthers hanging out were used for observation. Visual estimates were made using 1-10 scale.

Results and Discussion

Present study focuses on anther extrusion of rye x wheat derivative lines. Anther size and anther extrusion are more relevant floral trait for hybrid wheat. High anther extrusion gives a more chance to outcrossing. Martin (1990), Hucl (1996) and Singh (2006) they were also find natural outcrossing in cultivated wheat varieties up to 6.05% which has positive correlation with anther extrusion. From rye x wheat introgression sets large numbers of derivative lines were found to have high anther extrusion score over PBW343. The range for anther extrusion was 1 to 10. Wheat variety PBW343 achieve anther extrusion score (4) from both sets. In comparison derivative lines achieve highest anther extrusion score (10) from both sets, (Fig1, Graph 1 and 2). One hundred twenty five lines achieve anther extrusion score between (8-10) with percent increase (100-150). Among them twenty two lines namelyTWD5-5, TWD5-8, TWD5-42, TWD6-7, TWD6-8, TWD6-10, TWD6-10, TWD6-17 and TWD6-31 achieve extrusion score (10) with percent increase 150 over PBW343 While fifty seven lines namely TWD5-2, TDW5-4, TWD5-7, TWD5-11, TWD5-29 TWD6-6, TWD6-9, TWD6-18, TWD6-20 and TWD6-44 achieve extrusion score (9) with percent increase125 over PBW 343 and forty six lines namely TWD5-1, TWD5-3, TWD5-6, TWD5-34, TWD5-18, TWD6-4, TWD6-5, TWD6-12, TWD6-27 and TWD6-32 achieve extrusion score (8) with percent increase 100 over PBW343.



Graph 1: Frequency distribution for anther extrusion in the population of triticale x wheat derivatives



Graph 2: Frequency distribution for % Change of anther extrusion over PBW343 in triticale x wheat derivatives

Fig 1: Triticale wheat derivatives lines show anther extrusion, increase over PBW343

Complexity of the hybridization systems were explored as major limiting factors for hybrid wheat development. Chowdhary *et al.* (1994) Singh *et al.* (2007) they were suggested that the selection for long anthers, high rate of anther extrusion may be effective in promoting natural cross pollination. Floral characters which enable sufficient cross fertilization like more open flowering habit, duration of flower opening, improved anther extrusion in the male parent and stigma receptivity in the female parent more crucial for successful development of hybrids. Komaki and Tsunewaki (1981) find the significant association of anther extrusion and it was suggested that the selection for high anther extrusion promote outcrossing may result in the genotypes with more open pollination ability and these may be utilized as male parents to improve yielding ability. Singh *et al.* (2003) find positive and significant correlation between yield/plant and anther extrusion. As the conclusion of all the reviews and study these derivative lines may be used as donor parents for provision of sufficient pollen availability in a hybridization programme.

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