Original Research Article

Genetics of Free Threshability in Tetraploid Wheat

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A B S T R A C T

To study inheritance pattern of threshability, two non-free threshing varieties of dicoccum viz., DDK-1025 and DDK-1029 crossed with advanced free threshable line NIDW-295. The non-segregating (P₁, P₂ and F₁) and segregating (F₂, BC₁P₁ and BC₁P₂) were developed and evaluated on individual plant basis for the trait threshability. The chi-square method was followed in order to test goodness of fit and establish gene relationship. Inheritance pattern of free threshability found to be governed by single dominant gene and free threshability is dominant over non-free threshability in F₁ in both the crosses viz., DDK-1025 x NIDW-295 and DDK 1029 x NIDW-295. In the F₂ generations of both the crosses, observations displayed a good fit to the monogenic ratio of 3:1 for free threshability verses non-free threshability. Among the back cross generations, BC₁P₁ (F₁ X DDK 1025 or DDK 1029) generations of both crosses, the data was found to be in good fit with expected ratio of 1:1 for free threshable : non-free threshable. In case of BC₁P₂ (F₁ x NIDW-295), all the plants observed for free threshability fall under free threshable category, which was in conformity with expected free threshable to non-free threshable ratio of 1:0.

Keywords
Dicoccum wheat, Inheritance/genetics, Threshability, Free threshability and Chi – square test

Introduction

Dicoccum wheat (Triticum dicoccum Schrank Schulb) a hulled wheat, commonly called by different names viz., “Jave, Khapli, Samba, Sadaka, Kavada” etc. In the world, cultivation of these wheats is only confined to few mountainous marginal areas of Italy. In India it is traditionally cultivated in Northern Karnataka, Southern Maharashtra, Sourashtra region of coastal Gujarat, Nilgiris and Palanihilly areas of Tamil Nadu and Telangan region in Andhra Pradesh (Mahantashivayogayya, 2002). Dicoccum wheat differs from commercially available bread and durum wheats in cultivation practices. Due to its nutritional and therapeutic quality traits dicoccum wheats are preferred by many people. This wheat has a great demand in urban areas of central and southern India and also in Srilanka and Maldevas, but due to non-availability of this wheat consumption is often confined to people of growing areas. Non-availability of free threshing varieties, lack of scientific techniques regarding dehulling of dicoccum wheat, value addition, reddish grain colour of the wheat are some of the constraints. In India, dicoccum wheat is mainly processed for preparation of semolina and used in preparation of several conventional dishes like
godhi huggi, uppuma, sajjaka, madali, chapati, holige and also in preparation of pasta products like vermicelli (Reddy, 1996).

Scientific studies related to dicoccum wheat also reveal that they are nutritionally superior as compared to commercially available wheat with the high protein and dietary fibre contents (Bhuvaneshwari et al., 1998). Dicoccum based products are more tasty and soft (Reddy, 1996) have high satiety value and a potential of backing, parboiling and popping quality. Products have low digestibility, low glycaemic value and it has been considered as a therapeutic food in the management of diabetes (Yenagi et al., 1999), which is India’s leading health problem.

Dicoccum wheats differ from other wheats viz., bread and durum wheats for physical characteristics, nutritional and processing quality parameters. Non availability of free threshing varieties low yield and reddish grain colour are important constraints in cultivation and utilization. The loss incurred on dehulling can be recovered if free threshing dicoccum varieties are developed. The husked grains (non-free-threshing) are governed by the genetic locus ‘q’ and naked grains trait by ‘Q’ which is located of chromosome five of genome A (Morris and Sears, 1967). All Triticum diploid progenitors possess the non-free-threshing (NFT) habit, while both free-threshing (FT) and NFT forms occur in the tetraploid and the hexaploid groups (Kerber and Rowland 1974). The kernels of the NFT wheat are closely invested in the spikelet by tough tenacious glumes, lemma, and palea that are not readily detached with pressure or vigorous rubbing. Whereas, only slight rubbing or threshing action is required to separate the glumes from the spikelet of FT wheat to separate the grains. MacKey (1966) reported a polygenic system scattered through all three genomes that counteracts rachis brittleness and tough, tenacious glumes. A second system which suppresses these primitive tendencies is that of the Q factor located on chromosome 5A. Inheritance studies of threshability in synthetic hexaploids and ‘Canthatch’ indicated that a partially dominant gene, apparently introduced from the T. tauschii parent, results in NFT spikelets. Kerber and Rowland (1974), showed dominant gene for tenacious glume, Tg, in 2D of T. tauschii and q inhibits the expression of free threshing habit in synthetic hexaploids. Further, understanding the gene action of the threshability is of prime importance in emmer wheat as there is a great need to develop dicoccum varieties with free threshing habit. Hence, the present study aimed to investigate the inheritance pattern of threshability by makes use of advanced free threshable lines.

**Materials and Methods**

In order to investigate the genetics of threshability in tetraploid wheat, two non-free threshable red grains dicoccum lines (DDK 1025 and DDK 1029) were crossed with one free threshable amber grain durum line (NIDW 295). Segregating and non-segregating generations were developed viz., P₁, P₂, F₁, F₂, BC₁P₁ (F₁ back crossed with P₁) and BC₁P₂ (F₁ back crossed with P₂). These six generations were evaluated under replicated trial on individual plant basis.

For the trait threshability, all the six generations were screened and categorized as free threshable and non-free threshable. Threshability data of individual spikes was recorded after harvest. Spikes were threshed with hand, based on percentage of husked seeds obtained, classified as free threshable and non-free threshable. These observations recorded for individual plants were pooled and utilized for determining the total number of free threshable and non-free threshable for threshability trait in P₁, P₂, F₁, F₂, BC₁P₁ and BC₁P₂ generations. Further, chi-square method...
was followed in order to test goodness of fit and establish gene relationship. The results obtained are explained below.

**Results and Discussion**

In the cross DDK-1025 x NDIW-295 (Table 1a), it is clear that the parent DDK-1025 (P₁) was found to be non-free threshable (NF). All the 10 plants of F₁ generation were categorized as free threshable (F).

In case of F₂ population, out of 225 plants scored, 164 plants were registered as free threshable and 61 plants were found to be non-free threshable. Further, these observations displayed a good fit to the monogenic ratio of 3:1 for free threshability verses non-free threshability as indicated by low chi-square value of 0.535 (Table 2a). Among the back cross generations, out of 105 plants screened in BC₁P₁ (F₁ x DDK-1025), 50 plants observed as free threshable. The data was found to be in good fit with expected ratio of 1:1 (F:NF) with the calculated chi-square value of 0.238.

The back cross results further confirmed the F₂ monogenic F: NF ratio of 3:1. In case of BC₁P₂ (F₁ x NIDW-295), out of 108 plants observed, 106 fall under free threshable and 2 under non-free threshable category, which was in conformity with expected F: NF ratio of 1:0.

In another cross, DDK-1029 x NIDW-295 and DDK-1029 (P₁) recorded non-free threshability and NIDW-295 (P₂) recorded free threshability. The F₁ generation also showed free threshability (Table 1b).

Further, all the plants of segregating generations were observed for threshability trait. Out of 210 F₂ plants observed, 160 plants categorized as free threshable and 50 as non-free threshable. These observations displayed a good fit to the monogenic F₂ ratio of 3:1 for free threshable to non-free threshable, as it is indicated by low chi-square value of 0.158 (Table 2b.). A total of 110 BC₁P₁ (F₁ x DDK-1029) plants were observed in the cross DDK-1029 x NIDW-295 and 58 plants were categorized as free threshable and 52 plants as non-free threshable. Again this data was also found to be in good fit with expected ratio of 1:1 (F:NF) with the calculated chi-square value of 0.327 which is less than table chi-square value of 5.99 at 5 per cent with 2 degrees of freedom.

Out of 100 plants observed in BC₁P₂ (F₁ x NIDW-295) generation, which is a test cross, 96 plants categorized four free threshable and as non-free threshable. This was in conformity with expected F: NF ratio of 1:0 with the calculated chi-square value (0.16) less than table chi-square value.

All these results in both the crosses viz., F₂ ratio of 3:1, back cross generations ratio viz., BC₁P₁ ratio of 1:1 and BC₁P₂ ratio of 1:0 (F:NF) depicted that the trait non-free threshability is controlled by single recessive gene and free threshability is dominant over non-free threshability in F₁. Similar observations were evidenced by Villareal et al., (1996), Luo et al., (2000), Patil (2010) and Nagaraju et al., (2017).

Thresholdability is one of the important post-harvest traits which is primary interest of the dicoccum breeders. The caryopsis of non-free threshing wheat is closely invested in the spikelet by tough thick tenacious glumes that are not readily detached with pressure and vigours rubbing. On the other hand, only slight rubbing or threshing action is required to separate the glume from the spikelet of free thesing wheat to release the kernel enclosed between the lemma and palea. The glume tenacity is classified as easy as threshing as that of T. aestivum.
Table 1: Reaction of parents, F1, F2 and back cross generations of *T. dicoccum x durum* cross for threshability

| Generation | Free threshold | Non-free threshold | Total |
|------------|---------------|-------------------|-------|
| P1 (DDK1025) | 0             | 10                | 10    |
| P2 (NIDW295)  | 10            | 0                 | 10    |
| F1          | 10            | 0                 | 10    |
| F2          | 164           | 61                | 225   |
| BC1P1 (F1 × DD1025) | 50          | 55                | 105   |
| BC1P3 (F1 × NIDW295) | 106         | 2                 | 108   |

b. Cross: DDK-1029 × NIDW-295

| Generation | Free threshold | Non-free threshold | Total |
|------------|---------------|-------------------|-------|
| P1 (DDK1029) | 0             | 10                | 10    |
| P2 (NIDW295)  | 10            | 0                 | 10    |
| F1          | 10            | 0                 | 10    |
| F2          | 160           | 50                | 210   |
| BC1P1 (F1 × DD1029) | 58          | 52                | 110   |
| BC1P2 (F1 × NIDW295) | 96          | 4                 | 100   |

Table 2: Test of significance of segregation ratios for threshability in *T. dicoccum x T. durum* cross of wheat

| Generation | Observed | Total | Expected | Expected ratio | Chi-square value ($\chi^2$) | Table Chi-square value at 5% with 2 df |
|------------|----------|-------|----------|----------------|-----------------------------|---------------------------------------|
| F2         | 164      | 225   | 168.75   | 56.25          | 3 : 1                        | 0.535                                 |
| BC1P1      | 50       | 105   | 52.5     | 52.5           | 1 : 1                        | 0.238                                 |
| BC1P2      | 106      | 108   | 54       | 54             | 1 : 0                        | 0.037                                 |

NF - Non free threshable  
F - Free threshable  
BC1P1 – Back cross generation 1 with parent 1 (DDK-1025)  
BC1P2 – Back cross generation 1 with parent 2 (NIDW-295)

b. Cross: DDK-1029 × NIDW-295

| Generation | Observed | Total | Expected | Expected ratio | Chi-square value ($\chi^2$) | Table Chi-square value at 5% with 2 df |
|------------|----------|-------|----------|----------------|-----------------------------|---------------------------------------|
| F2         | 160      | 210   | 157.5    | 52.5           | 3 : 1                        | 0.158                                 |
| BC1P1      | 58       | 110   | 55       | 55             | 1 : 1                        | 0.327                                 |
| BC1P2      | 96       | 100   | 100      | 0              | 1 : 0                        | 0.16                                  |

NF - Non free threshable  
F - Free threshable  
BC1P1 – First back cross generation with parent 1 (DDK-1029)  
BC1P2 – First back cross generation with parent 2 (NIDW-295)
In this study dicoccum parents have brittle rachis and tough glumes and are non-free threshing with red pericap colour whereas, durum parents were free threshing and amber grained as they have non brittle rachis and easy threshing glumes as that of *T. aestivum*. Generally dicoccum wheats are not preferred by consumers due to its husked seed nature and red grain colour. The husked grains are governed by ‘q’ and necked grain trait by ‘Q’ which is located on chromosome five of genome A (Morris and Sears, 1967). Here the non-free threshing types are governed by recessive gene ‘q’.

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