***Original Research Article***

**FROM MILLET’S ‘PEARL’ TO DESERT’S ‘GOLD’: GHB 538 Improved (*Maru Sona*) EMERGES THROUGH GENOMICS-ASSISTED BREEDING**

**ABSTRACT**

**Downy mildew (DM) is the most devasting disease of pearl millet caused by *Sclerospora graminicola* (Sacc.) Schroet, continues to be a major biotic constraint to pearl millet production in India. Looking to this constraint, Junagadh Agricultural University, Jamnagar (Gujarat) in collaboration with ICRISAT (International Crops Research Institute for the Semi-Arid Tropics), Hyderabad decided to improve notified and popular pearl millet hybrid GHB-538 through marker-assisted backcross breeding due to which this hybrid make a comeback in an improved version. Christened *Maru Sona* or *Desert Gold* in the local language, the new version is equipped with the genes to fend off devastating downy mildew disease and was released for cultivation in Gujarat state and A1 zone dry regions of Rajasthan, Gujarat, Haryana during *kharif* season. The pearl millet hybrid GHB 538 Improved was developed by introgression of downy mildew resistance QTLs from P7-3-P13 and 863B-P2-P7 lines in the pollen parent J-2340 of earlier released GHB-538 with marker-assisted backcross method using foreground selection and notified at state and national level for *kharif* season cultivation. The screening against downy mildew of GHB 538 Improved was carried out under the downy mildew sick plot and yield trials testing work against original GHB-538 was carried out at state as well as national level across different locations. Compared to the original hybrid, *Maru Sona* shows markedly high resistance to downy mildew disease along with increase in grain yield (3.50 and 1.78%) and dry fodder yield (10.80 and 1.93%); it also hallmarks early flowering (44 and 45 days) at state and AICRP trials, respectively. It also shows resistance to other pearl millet diseases as well as good quality parameters.**

**Key Words:** downy mildew, pearl millet, early, EDV, marker, backcross

**1. INTRODUCTION**

Pearl millet [*Pennisetum glaucum* (L.) R. Br.] is an important cereal crop in arid and semi-arid tropical regions of Gujarat and Rajasthan. It is a significant source of dietary energy and nutritional security for poor farmers and consumers.

Downy mildew (DM) or green ear disease is the most devasting disease of pearl millet caused by *Sclerospora graminicola* (Sacc.) Schroet, continues to be a major biotic constraint to pearl millet production in India [1,2,3,4]. It is the most widespread and destructive diseases of pearl millet in India and Western Africa [3]. DM epidemics were not reported till the introduction of F1 hybrids. This disease, first reported in India [5], is present in more than 20 countries [6] and is a major factor limiting the full exploitation of the high yield potential of hybrids in India [7]. In India, DM epidemics caused substantial yield losses during 1970s and 1980s. Grain yield losses of 10% to 80% have been reported. The yield reducing potential of DM is very high and this was adequately demonstrated in HB 3, a popular hybrid, when pearl millet grain production in India was reduced from 8 million tons in 1970-71 to 5.3 million tons in 1971-72. This reduction was to a large extent due to DM epidemic in which yield in some fields were reduced by 60 to 70%. The estimated annual grain yield loss due to DM is approximately 20-40% [4,8,9]. But, this could be much higher under favorable conditions of disease development [4,10,11], where a susceptible cultivar is repeatedly grown in the same field. Grain yield losses due to DM can reach alarmingly higher levels when a genetically uniform pearl millet cultivar is repeatedly and extensively grown.

The cultural and chemical control measures have been worked out but use of resistant cultivars is the most cost-effective and sustainable management method of DM. Both conventional and molecular breeding methods have successfully been used in DM resistance breeding program [8,12]. In the molecular breeding program MAB method was used for transferring DM resistant QTLs into the hybrid parental lines [13]. Several DM resistant lines, such as IP 18292, 7042R and 700651 have been used in developing hybrid parental lines. A number of DM resistant QTLs effective against diverse Indian pathotypes of *S. graminicola* have been mapped on the pearl millet linkage groups and some of them have been transferred to the commercial B-lines (843B, 81B) and R-lines (H 77/833-2, ICMP 451). Development and commercial deployment of DM resistant version of HHB 67 is the first successful story of MAB in field crops in public domain in India [14].

Our earlier released early segment hybrid GHB-538 becomes susceptible to the DM disease, of which otherwise is a very popular and good hybrid. It is recommended for pearl millet growing A1 zone of India and moreover it is also recommended for *kharif*, summer and semi *rabi* cultivation in Gujarat. This hybrid is good for its consumer preferred yellow grain colour. Looking to these requirements, Junagadh Agricultural University, Jamnagar (Gujarat) in collaboration with ICRISAT (International Crops Research Institute for the Semi-Arid Tropics), Hyderabad efforts have been taken for the improvement of the GHB-538 through marker assisted backcross breeding due to which an improved version that shows resistant to DM. Hence, research will be helpful for the young scientist. Introgression of additional downy mildew resistance QTLs has not just enhanced downy mildew resistance but will also impart stability to downy mildew resistance and will significantly enhance the life span of GHB 538 Improved.

**2. MATERIALS AND METHODS**

GHB 538 Improved (*Maru sona*) is an essentially-derived variety (EDV) version of immensely popular pearl millet early segment hybrid GHB-538 released in 2002 and notified in 2003 for A1 zone dry regions (receiving less than 400 mm rainfall annually) of Rajasthan, Gujarat, Haryana and moreover it is also recommended for *kharif*, summer and semi *rabi* cultivation in Gujarat. The restorer line J-2340 Improved is a MAS improved version of J-2340 developed through molecular breeding by making use of the downy mildew (DM) resistant donor parents each carrying different DMR QTL. The donor parent P7-3-P13 contributed LG3 DMR QTL while, the donor parent and 863B-P2-P7 contributed LG1 and LG4 QTLs. These two donor parents were crossed to original male recurrent parent J-2340 resulting in two different crosses and populations. Each of the two populations was carry-forward using marker-assisted backcrossing (MABC) using foreground selection. The improved introgression lines in BC3F5 were crossed resulting in QTL heterozygote. This line was selfed for three generations to generate DMR double QTL introgression line carrying three QTLs (one from P7-3-P13 and two from 863B-P2-P7). The final DM resistant version of J-2340 Improved was derived from ((ICMR 11019-P27 × ICMR 11009-P17)-P101)-P1819). The resistance alleles pyramided improved hybrid developed by crossing the original seed parent (ICMA 95444) with the improved pollinator parent J-2340.

The screening against DM of GHB 538 Improved hybrid was carried out under the DM sick plot at different locations of Gujarat and yield trials testing against original GHB-538 was carried out at Jamnagar and other sub stations from 2018 to 2020 during *kharif* season. It is also tested as a testing code MH 2661 in AICRP on pearl millet crop improvement A1 zone trials for yield testing as well as plant pathology trials for screening against DM from 2021 to 2022 during *kharif* season.

**3. RESULTS AND DISCUSSION**

In state trials, GHB 538 Improved shows significant improvement in downy mildew resistance under field conditions along with 3.50% increase in grain yield and 10.80% increase in dry fodder yield over the original GHB-538. The average grain yield of GHB 538 Improved was 2589 kg ha-1 over 2502 kg ha-1 of GHB-538, while the average dry fodder yield of GHB 538 Improved was 6320 kg ha-1 over 5703 kg ha-1 of GHB-538 (Table 1).

In AICRP trials, it has also recorded 1939 kg ha-1 grain yield which was 1.78% higher over check hybrid GHB-538 with 1905 kg ha-1, while it has recorded average 4351 kg ha-1 dry fodder yield which was 1.93% higher dry fodder yield over check GHB-538 with 4268 kg ha-1 (Table 1).

**Table 1: Yield performance of pearl millet hybrid GHB 538 Improved in comparison with check**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Name of Entries** | **No. of testing locations** | **Average grain yield (kg ha-1)** | **% increase over**  | **Average dry fodder yield (kg ha-1)** | **% increase over** |
| **State Trials (*Kharif* 2018-2020)**  |
| GHB 538 Improved  | 10 | 2589 | - | 6320 | - |
| GHB-538 (c)  | 10 | 2502 | 3.50 | 5703 | 10.80 |
| **AICRP on Pearl Millet A1 Zone Trials (*Kharif* 2021 & 2022)** |
| GHB 538 Improved  | 19 | 1939 | - | 4351 | - |
| GHB-538 (c)  | 10 | 1905 | 1.78 | 4268 | 1.93 |

It has high level of resistant to downy mildew (1.8 and 1.5%) as compare to original version GHB-538 (10.7 and 3.6%) when tested against it at state and AICRP trials, respectively (Table 2). Further, it is also resistant against blast, rust, smut and ergot, diseases and in case of pearl millet major insect-pest, stem borer, shoot fly and *helicoverpa* infestation is less than the check and its falls under resistant category (Table 3).

**Table 2: The reaction of disease incidence on pearl millet hybrid GHB 538 Improved in comparison with check under natural field condition with check**

|  |  |  |
| --- | --- | --- |
| **Disease** | **State Trials** **(*Kharif* 2018-2020)** | **AICRP on Pearl Millet Trials** **(*Kharif* 2021 & 2022)** |
| **No. of trials** | **GHB 538 Improved** | **GHB-538 (c)** | **7042 S** **(DM Susceptible)** | **No. of trials** | **GHB 538 Improved** | **GHB-538 (c)** |
| Downy mildew (%) at 60 DAS  | 9 | 1.8(0.0-12.50) | 10.7(0.0-39.5) | 100.0(92.9-100.0) | 6 | 1.5(0.0-4.6) | 3.6(1.3-6.0) |
| Blast (Score 0-9) | 9 | 1.1(0.0-3.0) | 2.5(1.0-4.0) | **-** | 6 | 1.4(0.5-2.5) | 2.2(0.5-4.0) |
| Rust (%) at 60 DAS | 9 | 1.8(0.0-11.0) | 5.6(0.0-22.0) | **-** | 4 | 0.3(0.0-1.0) | 0.3(0.0-1.0) |
| Smut (%) at 60 DAS | **-** | **-** | **-** | **-** | 4 | 3.6(0.0-9.5) | 4.0(0.0-9.5) |
| Ergot (%) at 60 DAS | **-** | **-** | **-** | **-** | 2 | 1.8(0.0-3.5) | 2.5(2.0-3.0) |

Figure in parenthesis are range

**DM:** 0.1-5.0 % highly resistant; 5.1-10.0% moderately resistant; 10.1-25.0% Susceptible; >25% highly susceptible

**Blast** 1.0-3.0 score resistant; 3.1-5.0 score moderately resistant; 5.1-7.0 score susceptible; > 7 score highly susceptible

**Rust:** 0.0 to 20.00% resistant; 21.0 to 25.0% moderately resistant; >25.0% susceptible

**Table 3: The reaction of insect-pest incidence on pearl millet hybrid GHB 538 Improved in comparison with check**

|  |  |  |
| --- | --- | --- |
| **Disease** | **State Trials** **(*Kharif* 2018-2020)** | **AICRP on Pearl Millet Trials** **(*Kharif* 2021 & 2022)** |
| **No. of trials** | **GHB 538 Improved** | **GHB-538 (c)** | **No. of trials** | **GHB 538 Improved** | **GHB-538 (c)** |
| Shoot fly incidence at vegetative stage (%) | 3 | 2.5(0.0-5.0) | 8.2(6.4-11.1) | 5 | 4.4(0.0-6.7) | 4.7(0.0-8.2) |
| Shoot fly incidence at earhead stage (%) | 3 | 3.8(1.7-5.8) | 5.8(3.6-8.8) | 5 | 3.5(0.0-11.9) | 2.8(0.0-4.9) |
| Stem borer incidence at vegetative stage (%) | 3 | 4.8(3.3-10.3) | 13.8(11.3-22.5) | 2 | 0.0 | 0.4(0.0-0.8) |
| Stem borer incidence at earhead stage (%) | 3 | 4.0(3.5-6.8) | 11.4(3.8-10.3) | 2 | 2.5(0.0-5.0) | 1.2(0.5-1.9) |
| *Helicoverpa* larvae per 5 ear heads | 3 | 0.3(0.0-2.0) | 2.0(0.0-4.0) | 4 | 0.9(0.0-1.7) | 2.0(0.5-3.7) |
| Leaf roller damage score at earhead stage | **-** | **-** | **-** | 1 | 2.5 | 2.0 |

Figures in parenthesis is range

**Shootfly and stem borer:** 0.0% resistant; 0.1 to 5.0% moderate resistant; 5.1 to 10.0% tolerant; 10.1-20.0% susceptible; > 20.0% highly susceptible

***Helicoverpa* damage:** < 1 larva per 5 ear heads resistant; 1 to 5 larvae per 5 ear heads tolerant; 5.1 to 25 larva per 5 ear heads: susceptible

In case of important ancillary traits of GHB 538 Improved with check hybrid at state and AICRP trials were mentioned in table 4. The GHB 538 Improved earhead length increased and recorded 22.3 cm and 24.0 cm, without any change in days to 50% flowering (44 and 45 days).

The GHB 538 Improved being an EDV version of original GHB-538, retains its hallmark of early maturity (both improved version and original matures in 78 day) and its recorded plant height (196 and 172 cm), number of productive tillers per plant (3.0 and 2.4), earhead diameter (2.4 and 2.7 cm) and 1000 grain weight (9.2 and 8.8 g) at state and AICRP trials, respectively (Table 4). Additionally, its grain contains iron (53.0 and 43.3 ppm) and zinc (40.0 and 32.6 ppm) in state as well as AICRP trials, respectively which are higher than the decided bench mark level (Fe 42 ppm and Zn 32 ppm) (Table 5). This Improved hybrid have same consumer preferred grain colour as of original hybrid. The above similar type work was finding in pearl millet and first successful hybrid developed and commercial deployment of DM resistant improved version of HHB 67 through MAB in India [14,15].

**Table 4: Ancillary traits of pearl millet hybrid GHB 538 Improved along with check**

|  |  |  |
| --- | --- | --- |
| **Disease** | **State Trials** **(*Kharif* 2018-2020)** | **AICRP on Pearl Millet Trials** **(*Kharif* 2021 & 2022)** |
| **No. of trials** | **GHB 538 Improved** | **GHB-538 (c)** | **No. of trials** | **GHB 538 Improved** | **GHB-538 (c)** |
| Days to 50% flowering | 10 | 44 | 44 | 15 | 45 | 45 |
| Days to maturity | 10 | 78 | 78 | 14 | 78 | 78 |
| Plant height (cm) | 10 | 196 | 185 | 19 | 172 | 168 |
| No. of productive tillers / plant | 10 | 3.0 | 3.0 | 18 | 2.4 | 2.4 |
| Earhead length (cm) | 10 | 22.3 | 20.5 | 19 | 24 | 22 |
| Earhead diameter (cm) | 10 | 2.4 | 2.5 | 17 | 2.7 | 2.7 |
| 1000 grain weight (g) | 10 | 9.2 | 9.0 | 17 | 8.8 | 8.7 |

**Table 5: Grain biochemical parameters of pearl millet hybrid GHB 538 Improved along with check**

|  |  |  |
| --- | --- | --- |
| **Disease** | **State Trials** **(*Kharif* 2018-2020)** | **AICRP on Pearl Millet Trials** **(*Kharif* 2021 & 2022)** |
| **No. of trials** | **GHB 538 Improved** | **GHB-538 (c)** | **No. of trials** | **GHB 538 Improved** | **GHB-538 (c)** |
| Iron content (ppm) | 4 | 53.0 | 52.0 | 12 | 43.3 | 47.3 |
| Zinc content (ppm) | 4 | 40.0 | 42.0 | 12 | 32.6 | 33.0 |
| Protein (%) | 4 | 8.4 | 7.5 | 2 | 12.2 | 10.7 |
| Fat (%) | 4 | 5.4 | 5.6 | 2 | 5.0 | 4.9 |
| Carbohydrate (%) | 4 | 78.6 | 76.2 | - | - | - |

 **4. CONCLUSION**

GHB 538 Improved is a new version of earlier released early segment pearl millet hybrid GHB-538 which becomes susceptible to the DM disease, otherwise is a very popular and good hybrid for its consumer preferred grain colour along with preferable consumer traits. The efforts taken for the improvement of the original early maturing pearl millet hybrid GHB-538 through marker-assisted backcrossing (MABC) and marker-assisted selection (MAS) by introgressing three downy mildew resistance QTLs from three chromosomes/linkage groups (LGs) i.e. 1, 3 and 4 due to which an improved version that shows resistant to DM. Introgression of additional downy mildew resistance QTLs has not just enhanced downy mildew resistance but will also impart stability to downy mildew resistance and will significantly enhance the life span of GHB 538 Improved. The GHB 538 Improved shows significant improvement in downy mildew resistance under field conditions along with increase in yield over the original GHB-538 at state as well as national level trials. Further, it is also shows resistance reaction to other diseases of pearl millet. The infestation of major insect-pest *i.e.,* the stem borer, shoot fly and *helicoverpa* is less than the check hybrid so it’s come under resistant category.

**COMPETING INTERESTS DISCLAIMER:**

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

**DISCLAIMER (ARTIFICIAL INTELLIGENCE)**

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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