Effect of high temperature on growth and yield attributes of Indian mustard genotypes due to late sown

ABSTRACT

The present investigation entitled "Effect of high temperature on growth and yield attributes of Indian mustard genotypes due to late sown" was conducted in randomized block design (RBD) with 12th new promising mustard genotypes *viz*., Vardan, Ashirwad, NPJ-207, NPJ-208, RGN-403, PBR-417, DRMRIJ 16-3, DRMR-2035, RRN-911, RH-1556, RGN-368 and BPR 541-4 widely differing in their growth behavior during two consecutive years (2017-18 and 2018-19). Study their genotypic variability for morphological, yield, and its attributes under late sown conditions. Results revealed that growth in terms of plant height, biomass accumulation, branching behavior, leaf area, growth parameters, yield, and its components varied significantly among tested mustard genotypes during both years of study under late-sown conditions. Findings indicated that mustard genotypes *viz*., DRMRIJ 16-3, RGN-403, and RH-1556 recorded higher values of total branches plant^{-1}, leaf area (cm^2), dry matter accumulation at harvest (g), siliquae on different branches, number of seeds/siliqua, seed yield/plant, biological yield per plant, test weight, harvest index as compared to other genotypes under late sown condition.

Keywords: High temperature, late sown, mustard, growth, and yield

1. INTRODUCTION

"Indian mustard (*Brassica juncea* L.) is a crop of tropical as well as temperate zones requiring somewhat cool and dry weather for satisfactory growth and development. The high temperature at the flowering stage causes a reduction in seed yield as it may lead to pollen sterility. The estimated area, production, and yield of rapeseed mustard in the world were 36.68 million hectares, 72.42 million tonnes, and 1974 kg/ha, respectively, during 2017-18. Globally, India accounts for 19.8 % and 9.8 % of the total acreage and production" [1]. During the last seven years, there has been a considerable increase in productivity from 1846 kg/ha in 2010-11 to 1974 kg/ha in 2017-18 and production has also increased from 61.64 mt in 2010-11 to 72.42 mt in 2017-18. In India, it contributes the maximum to edible oil supply after soybean and occupied an area of about 6.07 million hectares with about 7.92 million tonnes of production and an average yield of 1304 kg/ha during 2016-17. "Mustard is a cool season crop, which requires a temperature range from 6 to 27°C, and follows the C_3 pathway for carbon assimilation at this temperature the plant achieves maximum CO^2 assimilation. Mustard is generally grown under rain-fed conditions and moderately tolerant to soil acidity. It requires well-drained soil with a pH near neutral" [33]. "In the atmosphere, these gases trap heat radiant from the earth and thus increase global mean temperature. This temperature rise may lead to altered geographical distribution and the growing season of agricultural crop maturity. The rise in temperature beyond a threshold level for some time sufficient to cause irreversible damage to plant growth and development is often defined as heat stress. In Uttar Pradesh, especially in eastern and north-eastern parts as well as the central and western region, the prevalence of heat stress at the terminal stage of mustard is inevitable in substantial acreage under rapeseed mustard due to delayed sowing after rice and mixed/intercropping mustard with wheat" [1]. "Climate change has increased the intensity of heat stress and heat stress due to increased temperature is an agricultural problem in many areas of the world as well as in the country. Under the late-sown condition, productivity declines primarily due to the shortening of the vegetative and reproductive phases. Late-sown Indian mustard is exposed to high temperatures coupled with high evaporative demand of the atmosphere, during the reproductive phase which consequently results in forced maturity, increased senescence, and low productivity" [2]. "The rise in temperature, even by a single degree beyond the threshold level is considered heat stress to the plants" [3,4].

2. MATERIALS AND METHODS

The field experiment was conducted at the oil seed research farm Kalyanpur, of C. S. Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh. "This farm is situated about 3 km away from the main campus of the university on the south side of G.T. Road runs towards Delhi. The experimental field was well-leveled and had assured irrigation facilities. The experimental place Kanpur is situated at a latitude of 26^0 28` North and longitude of $80^0$ 24`East. The altitude is about 129 m above mean sea level. It has a semi-subtropical climate. The average annual rainfall of the region is 762 mm. The soil is built from Gangetic alluvium. To know the important characteristics of experimental soil; the samples were drawn at a depth of 0-30 cm from different places in the experimental area randomly before sowing and application of fertilizers but after the land preparation. The experiments were laid out in a randomized block design with three replications. Twelve mustard genotypes *viz.*, Vardan, Ashirwad, NPJ-207, NPJ-208, RGN-403, PBR-417, DRMRIJ 16-3, DRMR-2035, RRN-911, RH-1556, RGN-368 and BPR 541-4 were sown under late sown condition during 2017-18 and 2018-19" [33]. All the data recorded on morphological parameters and yield contributory characters were statistically analyzed by the methods suggested by Fisher [5]. The standard error (S.E.) differences and critical difference (CD) value.

3. RESULTS

3.1 Plant height (cm) in different growth stages of plant

Pooled analysis of both year's data revealed that plant height recorded significantly higher in mustard genotypes RH-1556 (22.7, 73.3, 128.8, and 159.5 cm) and also RGN-403 (23.5, 72.3, 131.4, and 159.6 cm) at all observational stages such as pre-flowering, flowering post-flowering and at harvest stage while DRMRIJ 16-3 at flowering and harvest (73.4 164.7cm) and also

Vardan (73.7, 133.8 cm) gave the significantly maximum value of it at flowering and post-flowering stages under late sown condition. The minimum plant height recorded on pooled analysis with mustard genotype DRMR-2035 (18.2 cm) at pre-flowering, RGN-368 (60.4 cm) at flowering RGN-368 (107.2 cm) at post-flowering, and PBR-417 (131.0 cm) at harvest stage (figure 1).

3.2 Number of primary, Secondary, and tertiary branches per plant at harvest

Based on a pooled analysis of both years' data, revealed that genotype DRMRIJ 16-3 (24.3) statistically at par with RGN-403 (23.3) proved superior as both gave a significantly higher value of total branches per plant as compared to other genotypes under late sowing situation. Mustard genotypes RRN-911 (16.6) and RGN-368 (17.0) not performed well as these gave significantly the lowest values of total branches per plant under the given situation (figures 2, 3 and 4).

3.3 Leaf area (cm^2) / plant at different growth stages

Pooled analysis of both years' data revealed that the genotypes DRMRIJ 16-3 (413.3, 1076.6, 613.3 cm^2) followed by RGN-403 (403.3, 1023.3, 613.3 cm^2), and RH-1556 (390, 976.6, 599.9 cm^2) stood first, second, and third under their significantly larger leaf area at pre-flowering, flowering, and post-flowering stage, while genotypes RRN-911 (299.9, 776.6, 473.3 cm^2) and RGN-368 (319.9, 793.3, 493.3 cm^2) both stood the lowest position as it performed poorly and showed the lowest leaf area at above observational stages under late sown conditions (figure-5).

3.4 Dry matter production of different plant parts (g/plant) at pre-flowering stages

Pooled analysis of both years' data revealed that the genotypes Vardan, RGN-403, and DRMRIJ 16-3 had similar stem dry weight per plant (1.5 g) closely followed by PBR-417, DRMR-2035, RH-1556, and BPR 541-4 (1.4 g). Leaf dry weight in genotypes DRMR-2035 (2.2 g) followed by RGN-403, DRMRIJ 16-3 (2.1 g), and total dry matter accumulation per plant in genotypes DRMRIJ 16-3 (3.6 g), DRMR-2035 and RGN-403 (3.6 g) followed by Vardan (3.3 g) remained higher at pre-flowering stage under late sown condition. Genotype RGN-368 recorded the lowest dry weight of stem (1.1 g), leaves (1.4 g), and total dry matter accumulation (2.5 g), which stood the lowest position in this regard also as it performed poorly under late sown conditions (figures 6,7 and 8).

3.5 Dry matter production of different plant parts (g/plant) at harvest

Pooled analysis of both years' data showed that the dry weight of stem, siliquae, and total per plant ranged from 55.5 to 62.3, 15.2 to 21.2 g, and 70.9 to 82.6 g respectively. Mustard genotypes RGN-403 (82.6 g), DRMRIJ 16-3 (82.0 g), and RH-1556 (80.8g) performed better and had a significantly higher total dry weight per plant as compared to other genotypes tested under late sown condition (figure 9).

3.6 Number of siliquae on different branches and total/plant at harvest

Pooled analysis of data over the two years showed that genotype DRMRIJ 16-3, RGN-403, and RH-1556, produced a maximum number of siliquae on the main shoot, primary branches as well as secondary + tertiary branches than other genotypes. So far as the total number of siliquae per plant is concerned genotypes DRMRIJ 16-3 (461.5), RGN-403 (459.8), and RH-1556 (455.1) proved as superior as these produced a significantly higher value of this trait over the others mustard genotypes evaluated under such stress condition. On the other hand genotypes RRN-911 (434.7), RGN-368 (436.1), and PBR-417 (436.4) proved as inferior as these gave significantly the lowest value of total siliquae per plant in late sown condition compared to other genotypes of mustard tested (figure 10).

3.7 Number of seeds/siliqua

On the other hand genotypes, RRN-911 (8.4, 8.0) and RGN-368 (8.4, 8.9) performed poorly during both years of study under the late sown condition as both exhibited a significantly lowest value of it than other mustard genotypes. The other remaining genotypes showed several seeds/siliqua between 9.5 to 12.3 and 9.3 to 11.7 in the first year and second years, respectively. Genotypes RH-1556 (12.7), RGN-403 (12.6), DRMRIJ 16-3 (12.5), and Vardan (12.5) seeds/siliqua proved as superior mustard genotypes under late sowing stress as these pegged the significantly higher number of seeds/siliqua, while RRN-911 (8.2) and RGN-368 (8.7) appeared as a poor performer as both recorded significantly, the lowest number of seeds/siliqua on pooled analysis basis (figure-11).

3.8 Seed yield/plant (g)

Pooled analysis of both years' data resulted that the genotypes, DRMRIJ 16-3 (18.5 g) followed by RGN-403 (17.7 g) and RH-1556 (17.5 g) were found significantly superior in seed yield indicating that these were suitable genotypes for late sowing environments with higher seed yield potential over the others genotypes. Genotypes RRN-911 (12.6 g) followed by RGN-368 (13.1 g) were unable to perform better under the late sown condition as these exhibited significantly lowest seed yield over the rest of the genotypes and should be avoided for late sowing (figure12).

3.9 Biological yield/plant (g)

Pooled analysis of both years' data indicated a higher value of biological yield in genotype RGN-403 (82.5 g) followed by DRMRIJ 16-3 (81.9 g) and RH-1556 (80.8 g) while the lowest biological yield was recorded in RRN-911, RGN-368 (70.9 g) followed by PBR-417 (71.3 g), respectively under late sown condition (figure 13).

3.10 Test weight (g)

Pooled analysis of both years' data showed that the value of test weight appeared significantly higher in mustard genotype DRMRIJ 16-3 (4.5 g) followed by RGN-403 (4.3 g), RH-1556 (4.3 g), NPJ-208 (4.2 g) and Vardan (4.2 g) proved as superior genotypes than others under late sown condition. Genotypes RRN-911 (3.4 g) and RGN-368 (3.6 g) performed poorly as these retained significantly lower values of test weight under late-sown conditions (figure 14).

3. 11 Harvest index (%)

Pooled analysis of the data over the two years revealed that genotypes DRMRIJ 16-3 (22.7 %) followed by RGN-403 (21.6 %) and RH-1556 (21.5 %) emerged as significantly superior genotypes over the others under the late sown condition as these maintained the higher value of HI. Genotypes RRN-911 (18.2 %), RGN-368 (18.3 %), and PBR-417 (18.6 %) performed poorly as these expressed alower value of HI as compared to others grown under late-sown conditions (figure 15).

4. Discussion

It is revealed from the data presented in (figure 1) that mustard genotype RGN-403 recorded the highest plant height at pre-flowering, Vardan at both flowering and post-flowering, DRMRIJ 16-3 at harvest under late sown conditions while the minimum plant height recorded with mustard genotype DRMR-2035 at pre-flowering RGN-368 both at flowering and post-flowering and PBR-417 at harvest stage on pooled data basis. The reduction in plant height during delayed sowing might be due to a reduction in the duration of the vegetative growth stage, which slows cell expansion and growth [6]. A similar observation was earlier recorded by Kumari [7] under late sowing. Singh [8] also found that “the 26 November sown crop of Indian mustard caused a 22.8% reduction in plant height due to high-temperature stress probably related to a decline in photosynthetic products”. Similar results were also reported by Patel [9, 10, 11]. From the results, it appears that plant height is an inherent characteristic of genotypes which influenced by the prevailing environment under late sown conditions.

The number of primary, secondary, tertiary, and total branches per plant was counted at the harvest stage. Based on pooled analysis (figure-2,3 and 4) DRMRIJ 16-3 followed by RGN-403 and RH-1556 produced maximum primary branches as well as total branches per plant, whereas genotypes RRN-911 and RGN-368 did not respond better and produced the lowest number of primary and total branches per plant under late sowing stress. The remaining genotypes under the grown situation bear primary and total branches per plant in between the minimum and maximum mentioned above. These results were somewhat under the findings of Pradhan [12]. Among the evaluated genotypes RH-1556 followed by DRMRIJ 16-3 and RGN-403 produced a significantly higher number (> 11.0) of secondary branches per plant as compared to other genotypes whereas, NPJ-208 followed by DRMRIJ 16-3, DRMR-2035, and NPJ-207 produced higher number of tertiary branches per plant (>5.0) over the other under late sowing environment on the pooled basis. Under late sown stress Ashirwad and BPR 541-4 in respect of secondary branches per plant and RRN-911 and RGN-368 in respect of tertiary branches per plant did not perform better and produced the least number of these branches per plant as compared to other genotypes. Several branches per plant produced in different tested genotypes seem to maintain their inherent characteristics for branching behavior against high temperatures under late sowing. Similar results of varietal differences in branching behavior in mustard have been reported by Lallu and Dixit [13,14,15].

Data of leaf area/plant (cm^2)which was measured at the pre-flowering, flowering, and post-flowering stages presented in (figure 5) revealed that it varied significantly among tried genotypes during both years of study (2017-18 and 2018-19) as well as on pooled analysis basis. Among the genotypes on pooled analysis, basis DRMRIJ 16-3 had significantly higher leaf area followed by RGN-403 and RH-1556 at all observational stages *i.e.* pre-flowering, flowering, and post-flowering whereas, minimum leaf area per plant was displayed by RRN-911 and RGN-368 at above-noted stages under late sown stress. Genotypes having higher leaf area in the present study possibly seem to be associated with their inherent genetic potential maintained against high-temperature environments at all observational stages. The decrease in leaf area from flowering to siliquae development (post-flowering) may be due to the senescence of the leaf as a result of the diversion of assimilates to the reproductive sink. The remaining genotypes showed leaf area between minimum and maximum as described above. Similar findings aboutthe presence of high genetic variability were reported for this trait by Patel [9],and Pandey and Bandna [17] in mustard.

Dry matter accumulation in different plant parts increased till physiological maturity among all the genotypes of mustard grown under late sowing stress during both crop seasons. The increase in dry matter of plants was due to an increase in plant height, growth, and development of plant organs. Dry matter partitioning in different plant parts *viz*., leave, stem and total per plant at pre-flowering showed a significant genotypic variation among all the tested genotypes during both crop seasons. At pre-flowering stages (30 DAS), leaf dry weight was noted higher than stem dry weight in all tested mustard genotypes under late sown conditions. Based on pooled analysis (figure 6,7 and 8) during the vegetative phase among different genotypes DRMR-2035, DRMRIJ 16-3, and RGN-403 responded better as all produced higher leaf (>2.0 g) as well as total dry weight (>3.5 g) per plant as compared to other genotypes. Dry matter production of the stem (>1.4 g) realized higher in DRMRIJ 16-3, RGN-403, and Vardanatat at this stage under the late-sown situation. Genotypes RGN-368 and RRN-911 not performed better under provided situation as both produced a significantly lower value of stem (1.1, 1.3 g), leaf(1.4, 1.5 g), and total dry matter (2.5, 2.8 g) per plant as compared to in other mustard genotypes. The remaining other genotypes recorded the value of the dry weight of these plant parts in between the minimum and maximum described in the above genotypes.

Results on dry matter accumulation in stem, leaf, and total per plant at the flowering stage are presented in (figure-9), which revealed that this stage stems dry weight, was higher than leaf dry weight in all tested genotypes under late sown conditions. Based on pooled analysis DRMRIJ 16-3 (13.2 g) followed by NPJ-208 (12.2 g) and RGN-403 (11.7 g) appeared as superior mustard genotypes as these produced relatively higher stem dry weight per plant under the late sown situation, while contrary of this, PBR-417 (17.7 g) and RRN-911 (17.9 g)had accumulated lowest biomass as compared to other genotypes under the grown environment. At this stage, BPR 541-4 (8.5 g) produced lower stem dry weight and NPJ-207 (7.4 g) produced the lowest leaf dry weight as compared to other genotypes. The rest of the genotypes produced the dry weight of the above plant parts in between the minimum and maximum described in above mentioned genotypes.

Significant genotypic variation in dry matter partitioning leaf, stem, siliqua, and total dry weight per plant at post-flowering were noticed during both years of study under late sowing conditions. At this stage, dry matter accumulation in the stem realized higher than leaves in all the mustard genotypes sown in late November. Pooled analysis basis (figure-9) indicated that among different genotypes again DRMRIJ 16-3 followed by RGN-403 and RH-1556 also at this stage produced considerably higher biomass in different plant parts *viz*., leaf, stem, siliqua, and total dry weight at this observational stage. Genotypes *viz*., Vardan, NPJ-207, and NPJ-208 produced higher total biomass (>61.4 g) on the bases of pooled analysis. On the other hand, genotypes DRMRIJ 16-3, DRMR-2035, RGN -403 and RH-1556 produced higher leaf dry weight(>9.3 g) while the higher value of stem dry weight was recorded in NPJ-207 (44.3 g) under delay sowing. Again genotypes RRN-911 responded poorly under this situation and produced the lowest dry weight of stem, leaf, siliqua, and total per plant at the above-mentioned stage. The remaining genotypes recorded dry matter between the minimum and maximum of the genotypes mentioned above.

The dry weight of different plant parts *viz*., stem, siliquae and total per plant at harvest also showed significant genotypic variation among 12 promising mustard genotypes considered in the present study during both years under a late sown environment. Among the tested genotypes, RGN-403, DRMRIJ 16-3 and RH-1556 performed better and showed higher biomass accumulation in different plant parts *viz*., stem (>60.5 g), siliquae (> 19.0 g) and also total per plant (>80.0 g) based on pooled analysis, whereas the minimum dry matter accumulation in different plant parts and total per plants was recorded in RRN-911 followed by RGN-368 than other grown mustard genotypes under late sown stress situation. The remaining genotypes showed intermediate levels and had a value of dry weight in different plant parts between lower and higher than described in above mentioned genotypes. Growth variability in terms of stem, siliquae, and total dry matter production per plant, plant height, leaf area per plant, and branching behavior was obviously due to the inherent genetic potential of different genotypes and the environmental response under late-sown conditions. Genotypes *viz*., DRMRIJ 16-3, RGN-403, and RH-1556 which proved significantly superior in the present study under late sowing environment remained with higher value of branching behavior, leaf area; dry matter accumulation in different plant parts might be due to the ability of these genotypes for greater transfer of their photosynthate from source to sink site under terminal heat stress caused by delayed sowing. The varietal differences in dry matter accumulation and partitioning in different plant parts have been earlier reported by various research workers Pradhan [12,1819,11,20] also confirmed that delayed planting decreases the dry matter production.

The number of siliquaeborne on the different types of branches and also their total/plant were recorded which varied significantly among 12 mustard genotypes under late sowing during both 2017-18 and 2018-19. Data depicted in (figure 10) based on pooled analysis revealed that on primary branches a maximum number of siliquae were pegged in RGN-403 followed by DRMRIJ 16-3 and RH-1556 while the lower values of these were recorded in RRN-911 and BPR 541-4 as compared to other genotypes. Genotypes DRMRIJ 16-3 followed by RGN-403, RH-1556, and Vardanproduced a maximum number of siliquae on the main branch as well as on secondary + tertiary branches and also a total number of siliquae per plant under late sown condition over the other genotypes. RRN-911 and RGN-368 did not respond well as both adhered with the significantly lowest number of siliquae on main and total per plant as compared to other tested genotypes. Genotypes PBR-417 and RGN-368 produced a significantly minimum number of siliquae on secondary and tertiary branches per plant under late sown conditions. The remaining genotypes produced siliquae on different branches in the range between lower and higher recorded in above named genotypes. Hall [31] observed that "flowering is the most sensitive stage for temperature stress damage probably due to vulnerability during pollen development anthesis and fertilization leading to reduce crop yield". Genotypes with a higher number of siliquae per plant in the present study may be maintained their inherent potential to protect against temperature stress damage for flowering resulting from flower abortion against rising temperature under late sowing stress. These results corroborate the findings of Angadi [21, 22, 23, 24].

The data on the number of seeds/siliqua concerning late sown stress showed a significant variation among the tried genotypes as presented in (figure-11). Based on the pooled analysis, it was observed that genotypes RH-1556 followed by RGN-403, DRMRIJ 16-3 and Vardan had a significantly higher number of seeds/siliqua (>12.0) while the lowest value (<8.7) was recorded in RRN-911 followed by RGN-368. The remaining genotypes showed the number of seeds siliqua in the range of 9.1 to 11.5. Genotypes with higher seeds/siliqua in the present study may be maintained their inherent ability and did not show any negative effect of rising temperature on their seeds formation under late sowing stress. These results are following the findings of Giri [25,22, 15,16, 11].

Seed yield per plant also varied significantly among genotypes under late sowing which ranged from 12.6 to 18.5 (g) (figure-12). Amongst the tested genotypes DRMRIJ 16-3 followed by RGN-403, RH-1556, and NPJ-208 produced significantly higher seed yield per plant in the amount of 18.5, 17.7, 17.5 and 16.8 (g) respectively under late sowing stress conditions, while under this situation RRN-911 (12.6 g) and RGN-368 (13.1g) yielded the lowest seed yield per plant. Genotypes with higher seed yield in the present study may be attributed to higher biomass/plant, number of branches/plant as well as higher yield contributing traits in these cultivars. Similar genotypic differences in seed yield in late-sown brassica crops were also reported by Lallu [14,26, 27, 11, 28].

Genotypes showed a differential trend in their biological yield at harvest under late sowing stresses presented in (figure-13) which varied significantly among themselves. The maximum biomass production/plant (>80 g) was recorded in genotypes RGN-403 followed by DRMRIJ 16-3 and RH-1556, while minimum biological yield/plant (<71 g) was recorded in RRN-911 and RGN-368 at harvest as compared to other tested genotypes sown under late sowing during both the years of study. The findings of this study revealed that the genotypes having higher biological yield may be having the potential for greater transfer of their photosynthate from source to sink site under rising temperature caused due to late sowing stress. Similar results of genotypic variations have been reported by Kumar [29, 9].

Genotypes also exhibited significant variation in their 1000seed weight under delay sowing (last week of November). Results revealed that significantly higher test weight (>4.3 g) (figure14) was maintained by DRMRIJ 16-3, RGN-403, and RH-1556 under late sowing and showed a greater degree of tolerance to high post-anthesis temperature as compared to other genotypes.The bold seed size of these genotypes showed the existence of a sink tolerance mechanism to heat stress. The lower value of 1000 seed weight was noted while the lower value was noted in RRN-911 (3.4 g) and RGN-368 (3.6 g) grown situation over the other genotypes. The remaining genotypes had test weights in the range of 3.7 to 4.2 g. Similar results were also reported by Sardana[23,30] also found genotypic differences in test weight.

The Harvest index reflects the proportion of assimilated distribution between economic and total biomass [32]. Significant variation existed for harvest index among the evaluated mustard cultivars under a late sowing environment. Among the genotypes, the values of harvest index (figure-15) were recorded higher in DRMRIJ 16-3 (22.7%) followed by RGN-403 (21.6%), RH-1556 (21.5%) and NPJ-208 (21.2%) and the lower value was noted in RRN-911 (18.2%) and RGN-368 (18.3%) under late sowing as compared to other genotypes. The remaining genotypes had a value of harvest index in the range of 18.6 to 21.1%. It is evident from the above findings that those mustard genotypes having a higher value of HI % seem to be more efficient in transferring their photosynthate in a balanced manner to developing seed under increasing temperature during the reproductive phase under late sowing stress. Similar results for harvest index in mustard were also reported by Lallu [14,29].

5. CONCLUSION

The conclusion of the present study revealed that significant genotypic variability existed among evaluated mustard genotypes in growth, and yield attributes due to late sown. Among different mustard genotypes DRMRIJ 16-3, RGN-403, and RH-1556 were found better performers under late-sown conditions. These genotypes were characterized by the higher value of plant height, branches per plant, leaf area, and dry matter production. These genotypes also recorded higher seed yield per plant, number of siliquae per plant, seeds per siliqua, test weight, as well as high harvest index.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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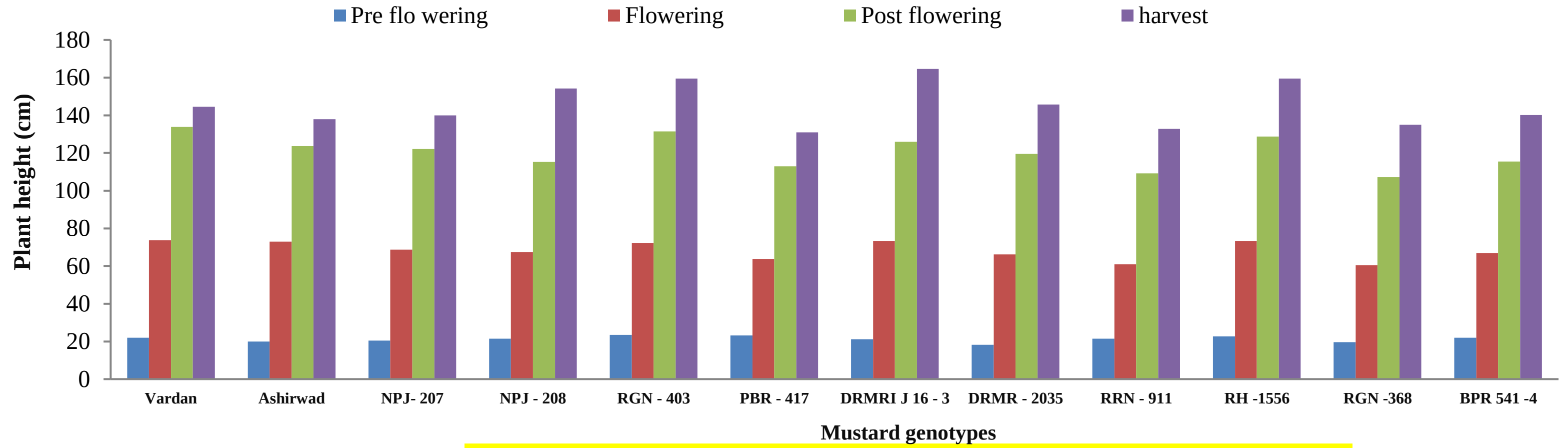


Figure-1. Plant height at different growth stages of plant (Pooled basis)

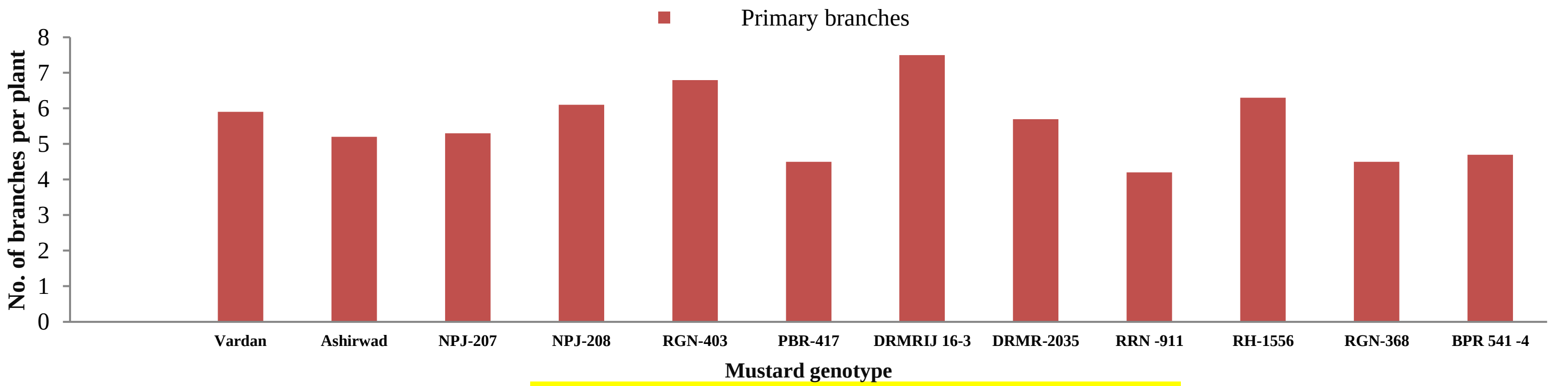


Figure- 2. Primary branches/plant at harvest (Pooled basis)

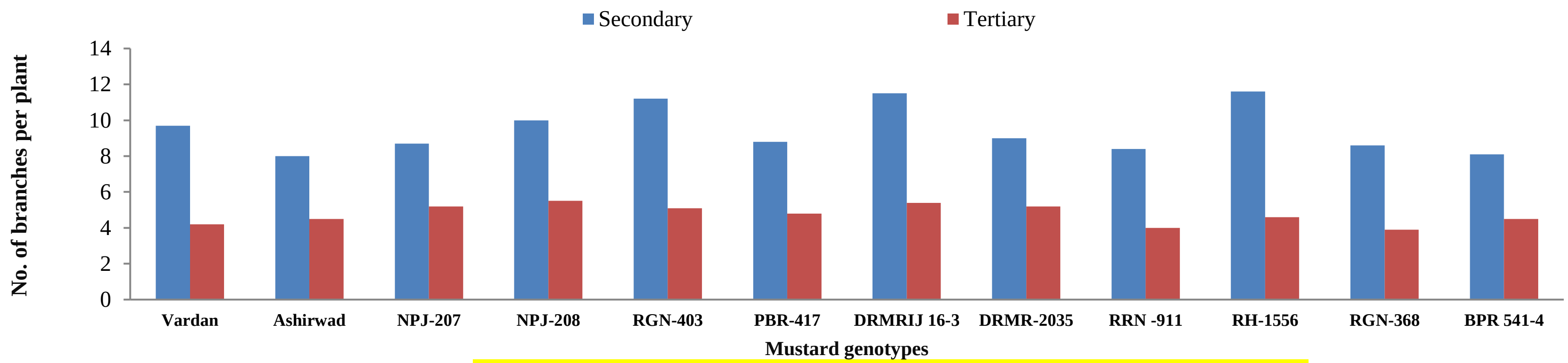
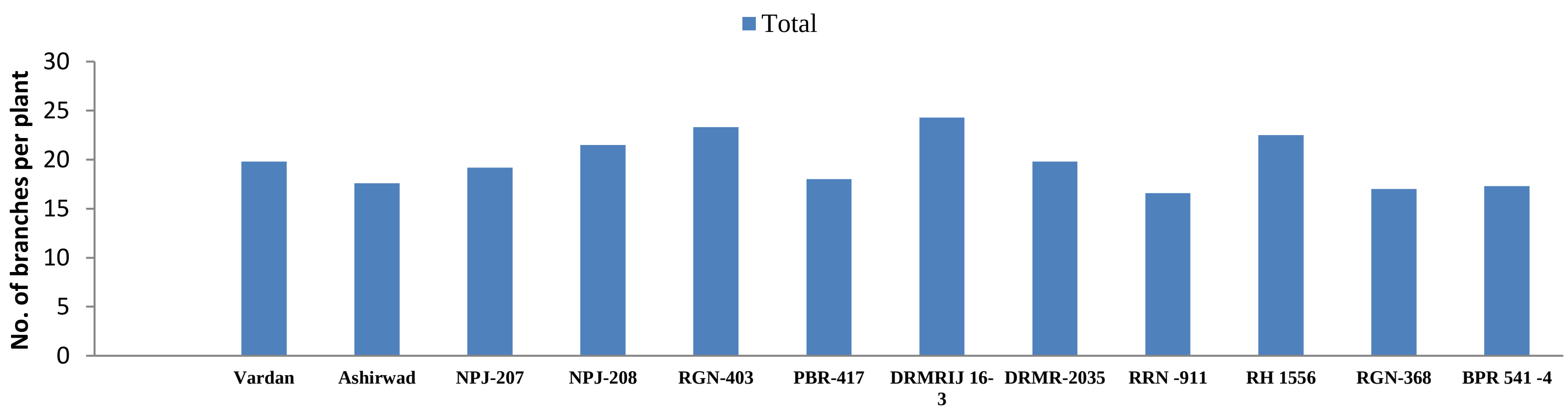


Figure-3. Secondary and tertiary branches/plant (No) at harvest (Pooled basis)



Mustard genotype

Figure- 4. Total branches/plant at harvest (Pooled basis)

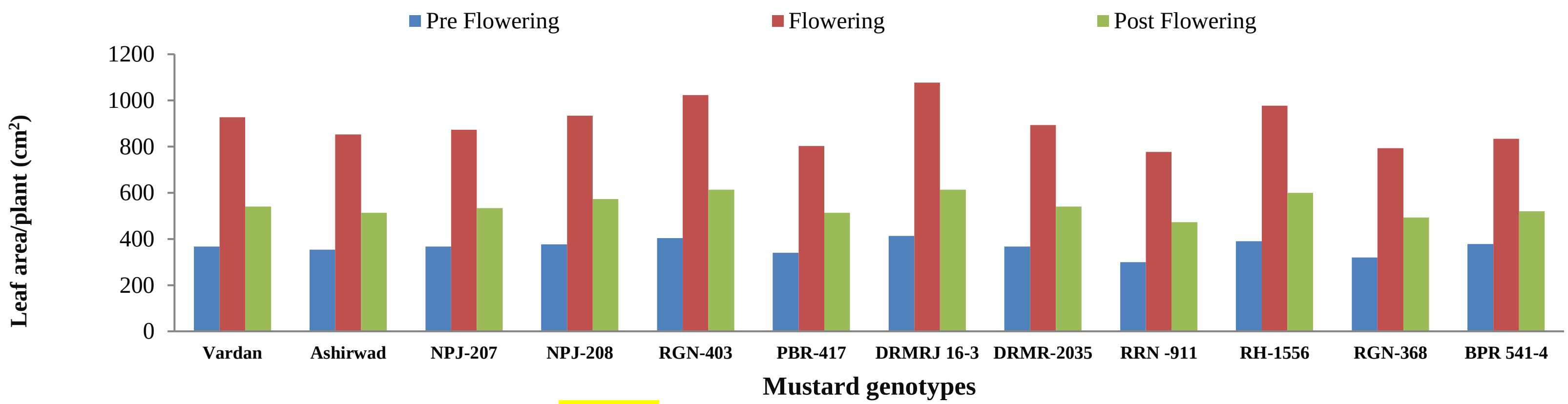


Figure- 5. Leaf area / plant at different growth stages (Pooled basis)

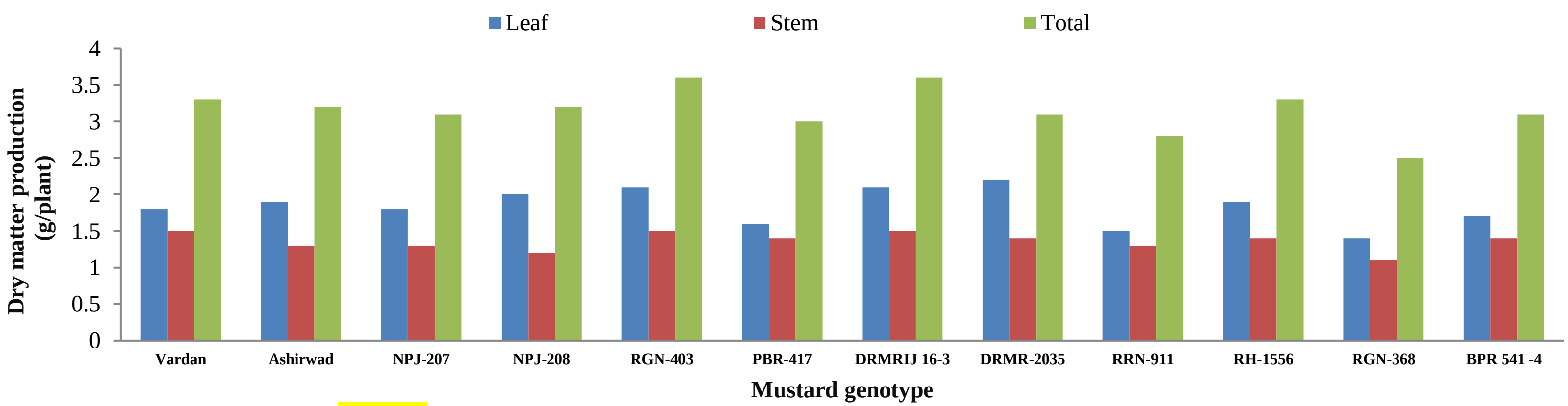


Figure- 6. Dry matter accumulation of different plant parts at pre flowering stages (Pooled basis)

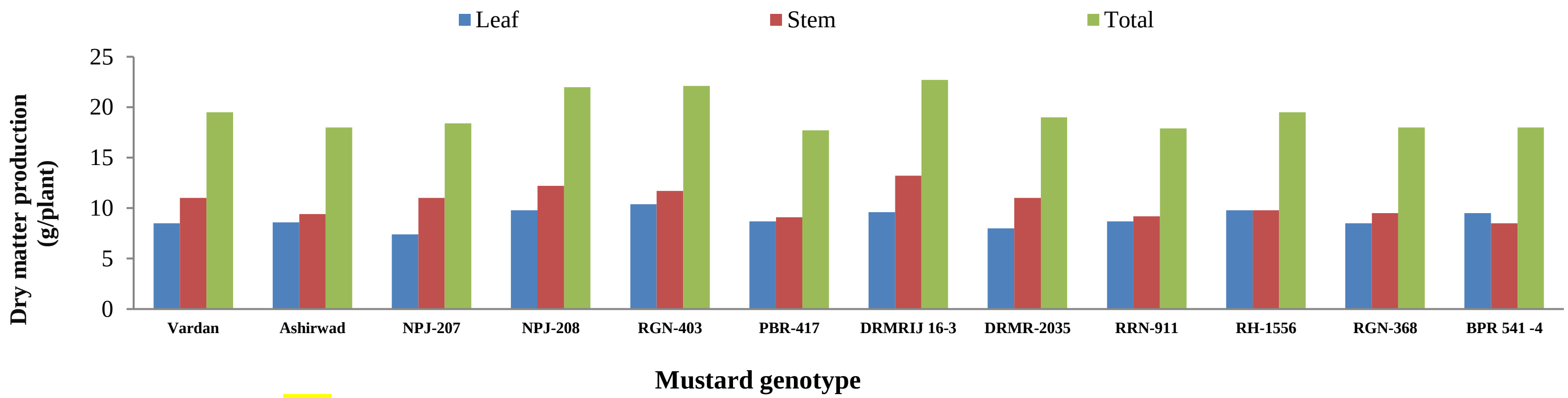


Figure- 7. Dry matter accumulation of different plant parts at flowering stages (Pooled basis)

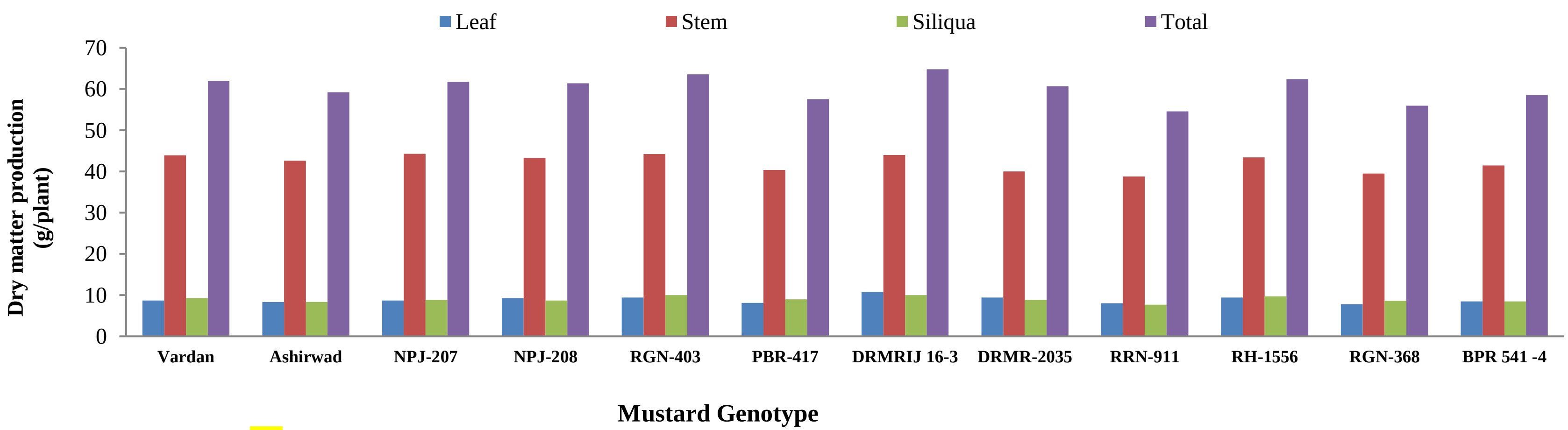


Figure- 8. Dry matter accumulation of different plant parts at post flowering stages (Pooled basis)

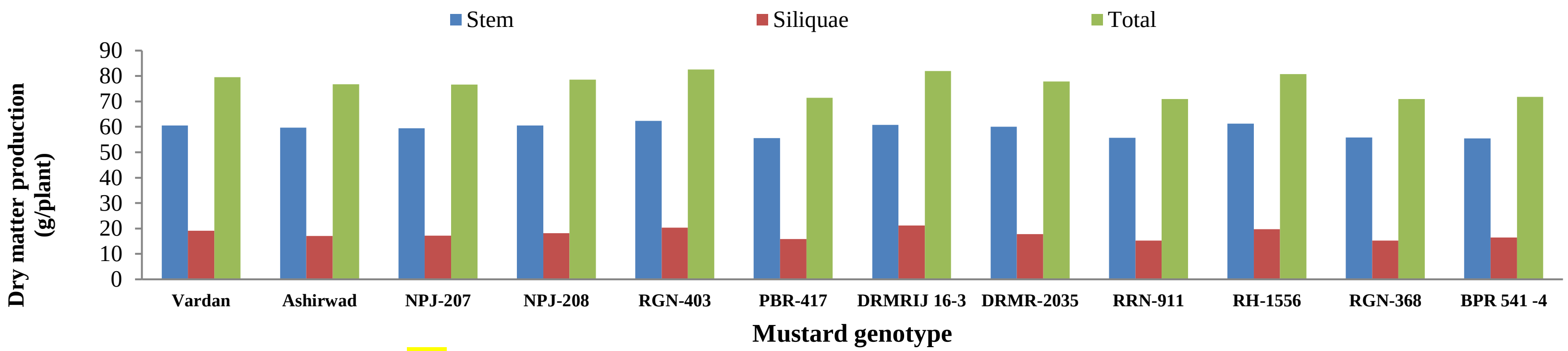


Figure- 9. Dry matter accumulation of different plant parts at harvest stages (Pooled basis)

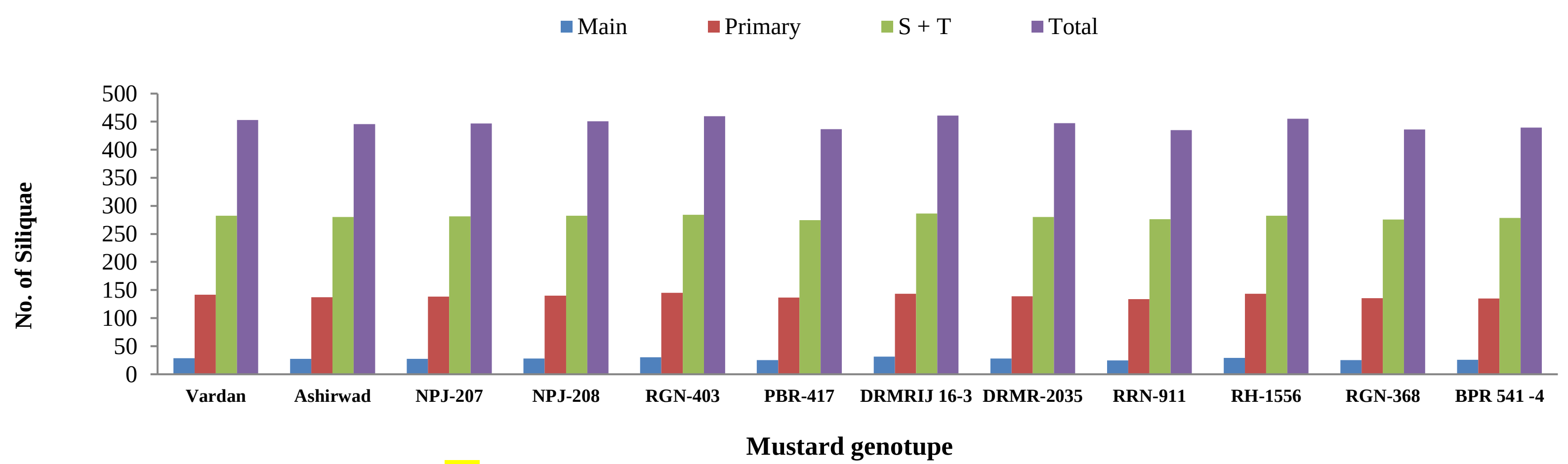


Figure- 10. Siliquae on different Branches and total / plant at harvest (Pooled basis)

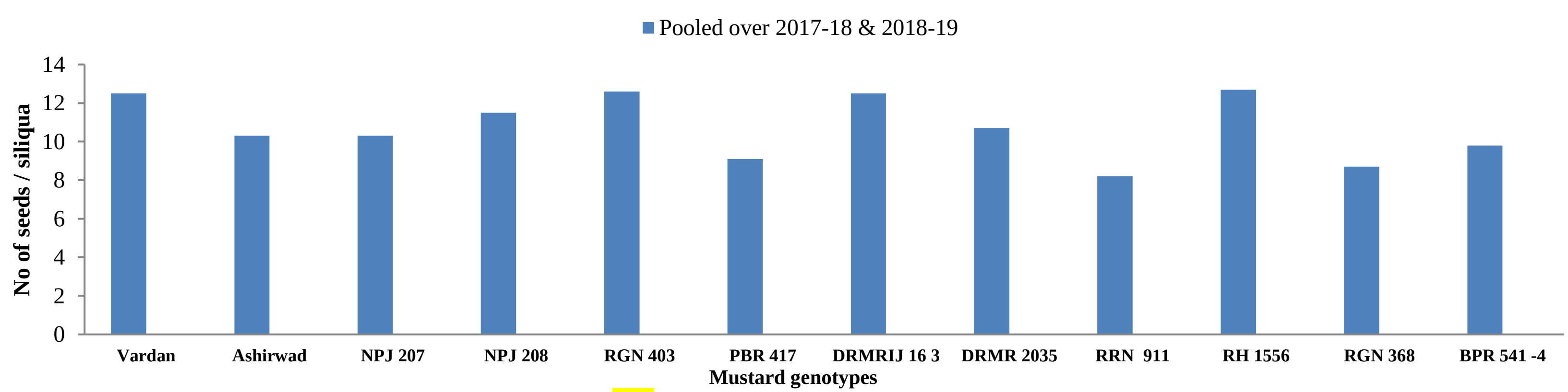


Figure-11. No of seeds / siliqua (Pooled basis)

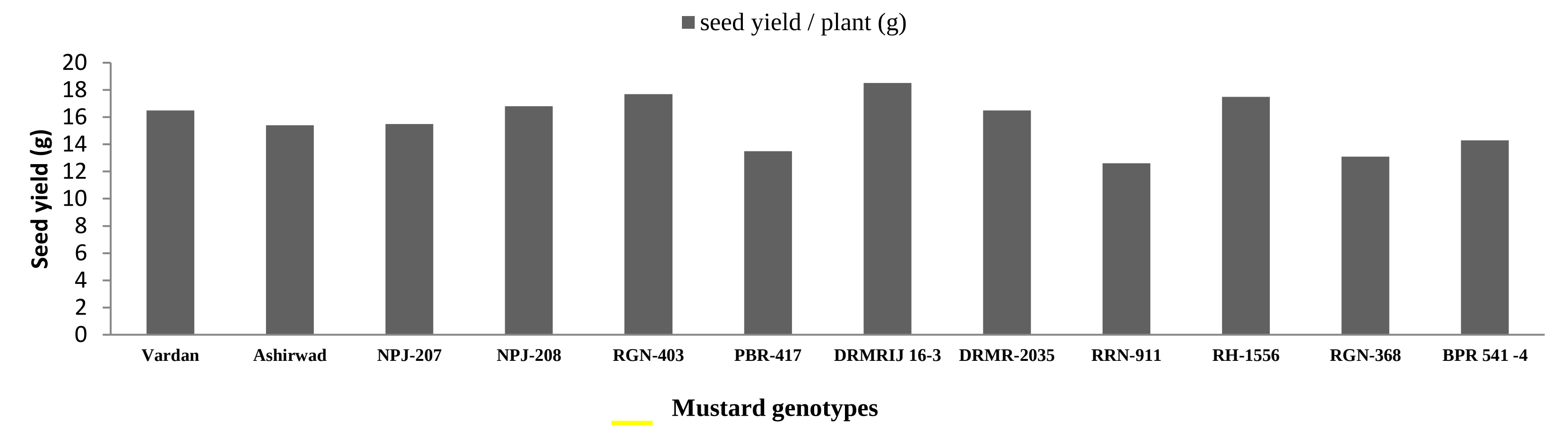


Figure- 12. Seed yield/plant (Pooled basis)

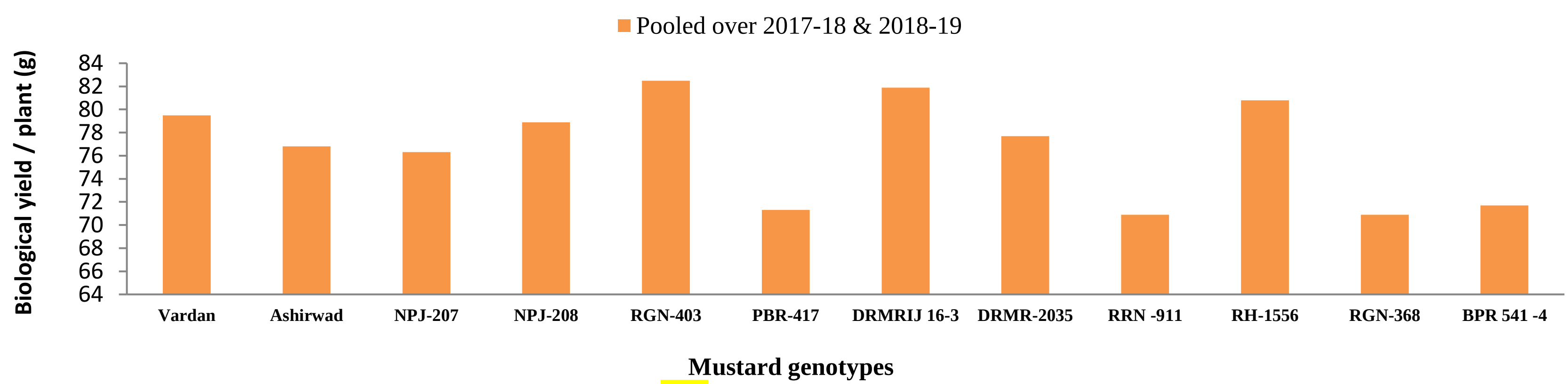


Figure- 13. Biological yield / plant (g)

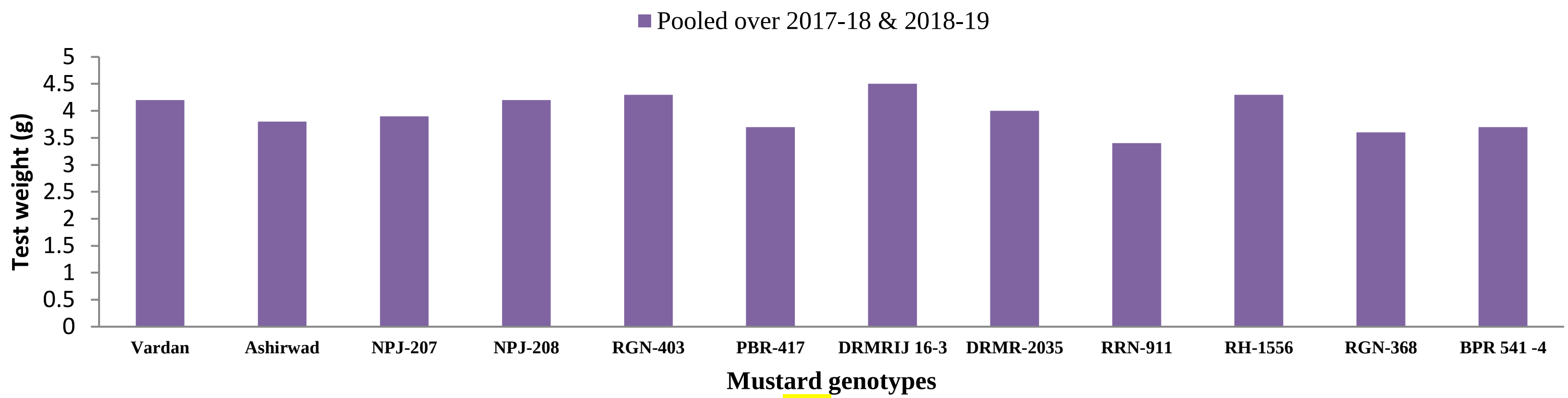


Figure- 14. Test weight

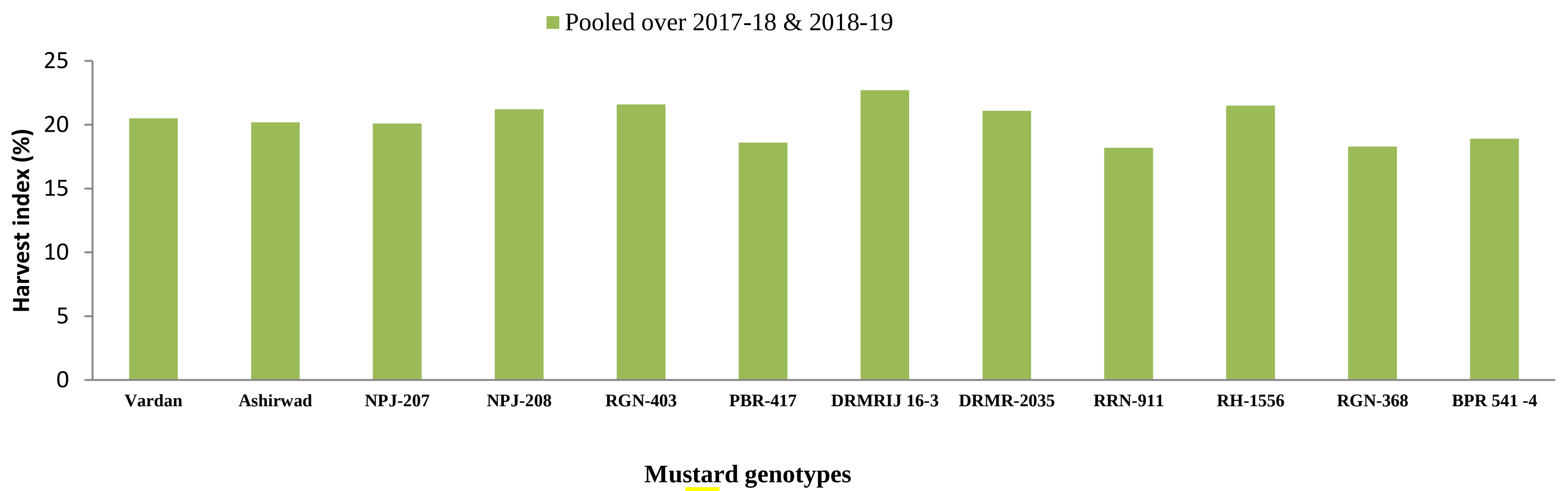


Figure- 15. Harvest index