severe cases. Besides pod yield, the foliar fungal diseases also effect both quantity and quality groundnut haulms rendering them unfit to use as fodder. Genetic resistance is the economical and sustainable option to overcome the pod yield losses and fodder quality deterioration.

A major quantitative trait loci (QTL) for rust resistance explaining up to >80% phenotypic variation was identified from a resistant variety, GPBD 4. Marker assisted backcrossing (MABC) approach was used to transfer rust resistance QTL into three popular susceptible varieties, JL 24, TAG 24 and ICGV 91114. They belong to Spanish bunch type. JL 24 and TAG 24 are popular groundnut varieties cultivated extensively in India, and ICGV 91114 is a drought tolerant variety. Foreground screening for QTL region was carried out using four linked markers which included one dominant (IPAHM103) and three co-dominant (GM2079, GM1536, GM2301) markers. Markers were not used for background screening, but selection for recurrent parent phenotype was based on morphological traits. In BC_2F_2 and BC_3F_2 generations several plants with linked marker loci in homozygous condition were identified, selfed and advanced to next generation. Subsequently, from $BC_{2/3}F_3$ onwards, generation advancement was done based on morphological selection towards recurrent parent phenotype. Best introgression lines were selected in $BC_{2/3}F_6$ generation based on disease reaction and phenotype.

Combing foliar fungal disease resistance with early maturity was the most significant outcome of the precision breeding program using MABC. Eighty-one improved introgression lines were identified with a disease score of 2 at 90 days after sowing (DAS), on a scale of 1-9, similar to the donor resistant parent, GPBD 4, and exhibited maturity duration and yield parameters similar to the recurrent parent. A replicated evaluation trial was conducted during 2013 rainy season at ICRISAT-Patancheru under disease pressure. Infector rows were sown and inoculum was sprayed to ensure adequate disease pressure. The disease score on TMV 2, a highly susceptible line used as infector is 8-9 at 90 DAS. The introgression lines recorded a pod yield increase of 56-96% over their respective recurrent parents in disease infected environment. The hundred seed weight (HSW) of these lines ranged from 31 to 39 g. The lines showed great potential for increasing pod and fodder yield compared to their susceptible parents. The haulm quality parameters of recurrent parent and introgression lines were at par.

In India, these are the first introgression lines of groundnut derived using MABC approach. Earlier, MABC derived groundnut varieties were developed in USA for resistance to root-knot nematode and enhanced oil quality. Multi-location evaluation of the foliar fungal disease resistant introgression lines is expected to result in release of these varieties at national and state level. The trials will be conducted in 2015 rainy season in six major groundnut growing states of the country under a partnership project involving ICAR-Directorate of Groundnut Research, ICRISAT, Tamil Nadu Agricultural University, Mahatma Phule Krishi Vidyapeeth, Acharya N G Ranga Agricultural University and University of Agricultural Sciences-Dharwad.

****

High yielding-high oil-wilt resistant breeding lines in safflower

K ANJANI, M D SHARIF BABA, R D PRASAD, PRADUMAN YADAV, DEMUDU NAIDU P

Directorate of Oilseeds Research, Hyderabad
Email: mdshariffbaba.apgc@gmail.com

Fusarium wilt caused by *Fusarium oxysporum* f sp. *Carthami* Klisiewicz and Houston is a major disease in safflower. Sources of resistance to Fusarium wilt among the vast collections of safflower germplasm were very few. The multiple crossings effected between susceptible high yielding lines and the wilt resistant breeding lines resulted into identification of several wilt resistant lines. Among them, six lines found to be stable for wilt resistance (<20% wilt incidence) over years of screening in wilt sick plot. These lines have exhibited 73-105% superiority in seed yield and 88-139% superiority in oil yield over the high yielding national check variety, A1 when tested in the research farm of the Directorate of Oilseeds Research, Hyderabad. One of these entries *viz.,* DSI-101 when tested for yield performance at 19 locations in Initial Varietal Trial (IVT) of AICRP (Safflower), recorded 18.3% higher seed yield and 26% higher oil yield over the highest yielding national check variety, A1 under irrigated conditions and 2.7% higher oil yield over A1 and near on par with A1 with respect to seed yield under rainfed conditions. It also exhibited resistance to Fusarium wilt in multilocation wilt sick plots in IVT.

Fusarium wilt inflicted by *Fusarium oxysporum* f sp. *Carthami* Klisiewicz and Houston is a major yield losing disease in safflower (*Carthamus tinctorius* L). Cultivating wilt resistant cultivars is an effective means to control this soil borne

disease. A very few accessions among vast germplasm collections of safflower were reported to be resistant to Fusarium wilt (Klisiewicz, 1980, Klisiewicz and Urie 1982). Diverse sources of resistance are needed to combat this disease. Several progenies in F_5 generation of multiple crosses attempted between susceptible high yielding breeding lines and resistant breeding lines were screened against wilt in wilt sick plot over years. Thus identified stable wilt resistant breeding lines (<20% wilt incidence) were evaluated for seed and oil yield performance. The results of the evaluation trails were discussed in the present paper.

Several advanced generation (F5) progenies of crosses between elite high yield breeding lines and resistant breeding lines, 96-508-2-90 (Anjani et al 2005), MS 6 (Y) x IP 52, 96-506-1-21 were tested for wilt resistance in wilt sick plot at the Directorate of Oilseeds Research (DOR), Hyderabad. The lines found resistant in first year were further confirmed for wilt resistance in wilt sick plot for 2-3 contiguous years. Thus identified several stable wilt resistant (<20% wilt incidence) advanced generation lines were evaluated along with a high yield check variety, A1 in different trials in RBD with three replications and 45 x 20 cm spacing at DOR, Hyderabad in 2011-12. The plot size was 30 sq.m/entry/replication in each trial. The data on seed yield (kg/ha), oil content (%), 100-seed weight (g), plant height (cm), days to 50% flowering and maturity were recorded. The recommended plant protection measures were given to trials as and when required. Oil content was measured using NMR. One light irrigation with sprinklers was given after sowing to ensure good plant stand. The statistical analysis of the data was done using INDOSTAT statistical software, INDOSTAT Services, India. One entry, w-05-2039-10-p2-p4-p5 was evaluated as DSI-101 at multiloctions in Initial Varietal trial (IVT) of All India Coordinated Research Project (AICRP) on Safflower in 2011-12. It was also screened against Fusarium wilt in maultilocation sick plots under IVT.

Table 1. Seed yield performance of wilt resistant lines

Entry	Seed yield (kg/ha)*	Oil yield (kg/ha)*	Plant stand/ha	100-seed weight (g)	Oil (%)
w-05-2039-10-p1-p6-p7-p6	1196 (90)	397 (119)	92.22	4.34	33.23
w-05-2039-10-p1-p6-p13-p24	1170 (86)	384 (112)	88.89	5.02	32.87
w-05-2028-6-p1-p2-p1-p15	1106 (75)	342 (88)	82.59	4.16	30.95
w-05-2039-10-p1-p1-p5-p26	1091 (73)	362 (100)	88.15	4.59	33.20
w-05-2039-10-p2-p4-p5	1344 (105)	428 (139)	84.81	6.07	31.90
w-05-2035-5m-p9-p4-p1-p6	1030 (97)	312 (108)	75.56	5.14	30.38
A1 (check)	522-655	150-181	58-85	5.4-6.4	27-28
CV (%)	11-19		16-21	7-10	2.7-7.6
CD (*P*=0.05)	180-354		27-33	0.710	1.8-4.9

*Figures in parentheses indicate percent increase over the check A1.

All entries reached to 50% flowering between 80-85 days after planting and maturity in 125-135 days. Six wilt resistant breeding lines consistently exhibited superior performance over the national high yielding check variety, A1. The increase in seed yield over A1 among these entries was from 73-105% while the increase in oil yield was from 88-139% (Table 1). The highest yield increase was realized from w-05-2039-10-p2-p4-p5 followed by w-05-2035-5M-p9-p4-p1-p6. These six entries recorded higher oil content (30-33%) as compared to the check, A1 (27-28%). The entry w-05-2039-10-p1-p6-p7-p6 recorded the highest oil content (33.23%) followed by w-05-2039-10-p1-p1-p5-p26 (33.2%). The 100-seed weight among the entries was between 4.16-6.07 g while it was 5.4-6.4 g in A1. The entry, w-05-2039-10-p2-p4-p5 exhibited the highest 100-seed eight (6.04 g) as well the highest yielding ability (1344 kg/ha) and high oil content (31.9%). This entry when evaluated as entry No. DSI-101 in IVT of AICRP (Safflower) at multilocations during 2011-12, yielded 18.3% mean higher seed yield (2076 kg/ha) and 26% higher oil yield (621 kg/ha) than A1 (1754 kg/ha seed yield; 492 kg/ha oil yield) under irrigated conditions (11 locations). And under rainfed conditions (8 locations) in IVT, DSI-101 yielded 5% (1246 kg/ha) lower than A1 (1316 kg/ha) but recorded 2.7% higher oil yield (379 kg/ha) than A1 (369 kg/ha). The mean oil content recorded in DSI-101 under rainfed conditions in IVT was 31% while it was 30% under irrigated situations whereas the oil content in A1 was 28% under rainfed and irrigated conditions. The mean 100-seed weight over 19 locations was 5 g in DSI-101 was 5 g while it was 5.75 g in A1. The mean hull content recorded in DSI-101 was 48.3% and 50.5% in A1. The mean number of seeds/capitulum was 31 in DSI-101 and 26 in A1. The mean Harvest Index (HI) of DSI-101 was 28% while A1 had 26% HI. DSI-101 exhibited 17.8% wilt incidence at Phaltan and 12.5% wilt incidence at DOR, Hyderabad. The six high yielding wilt resistant entries reported in the present paper would be utilized as male parental lines in safflower hybrid development programmes as sources of high yield coupled with high oil and wilt resistance.

REFERENCE:

Anjani K, Harvir Singh and Prasad R D. 2005. Performance of multiple resistant line of safflower (*Carthamus tinctorius* L.). *Indian Journal Agriculture Science,* **75**: 178-179

Klisiewicz J M. 1980. Safflower germplasm resistant to Fusarium wilt. *Plant Disease*, **64**:876-877

Klisiewicz J M and Urie A L. 1982. Registration of Fusarium wilt resistant safflower (*Carthamus tinctorius*) germplasm. *Crop Science,* **22**: 165

****

Genetic variability and trait association analysis of Indian mustard (*Brassica juncea*) genotypes under heat stress and normal environments

BHAGIRATH RAM, V V SINGH, B K SINGH, H S MEENA, A KUMAR AND DHIRAJ SINGH

ICAR-Directorate of Rapeseed Mustard Research, Bharatpur, Rajasthan 321 303

Email: bhagirathram_icar@yahoo.com

The global air temperature is predicted to rise by 0.2 °C per decade, which will lead to temperatures 1.8–4.0 °C higher than the current level by 2100 (IPCC, 2007). In India, rapeseed- mustard constitutes an important group of oilseed Brassica crops, and of these, Indian mustard [*Brassica juncea* (L.) Czern and Coss] is an important edible oil yielding crop accounting for about 80% of the cultivated area in North- Western parts of India (Singh *et al.*, 2014). Indian mustard is very sensitive to heat stress at early seedling stage. Although, early sowing has many advantages, the early sown-crop encounters high temperature stress, which results in a significant yield loss. Research on the direct effect of high temperature stress at the seedling stage in *Brassica juncea* is lacking. Hence, there is an urgent need for evaluating high temperature stress characteristics of *Brassica juncea.* Keeping this in view, an attempt has been made to identify superior genotypes of Indian mustard for high temperature stress tolerance which could be utilized for future breeding programmes.

The experiments were conducted at the experimental farm, DRMR, Bharatpur (77.27^{0}E **longitude**; 27.12^{0}N **latitude** and 178.37 m above mean sea level), India during *rabi* 2012-13 and 2013-14 under heat stress and normal temperature situations. Two hundred seeds of each genotype including two checks (BPR-543-2 and RH-30), were sown under heat stress and normal temperature conditions in crbd with three replications. The crop was raised strictly under conserved moisture conditions. All genotypes were grown in two rows of five meter length; with row to row and plant to plant spacing of 30 cm and 10 cm, respectively. Growth and physiological characters, including, percent population survival at 10 days after sowing (PPS 10DAS) and percent population survival at 25 days after sowing (PPS 25DAS), percent membrane stability index (PMSI), percent excised-leaf water loss (PELWL), percent relative water content (PRWC), percent water retention capacity of leaves (PWRCL), seed yield per plant (g), 1000-seed weight (g) and percent oil content were recorded from five randomly selected plants of each genotype. Mean data were subjected to analysis of variance (ANOVA) as suggested by Panse and Sukhatme (1978). Genetic parameters and genotypic correlations in all possible combinations were worked out as per standard procedure.

The mean sum of squares due to genotype and environment interactions was found highly significant for all the traits under study except oil content. High PCV and GCV were observed for PMSI (52.35, 30.30), seed yield per plant (42.23, 26.96), PPS 25DAS (39.10, 35.37) and PWRCL (30.44, 23.66). High genotypic and phenotypic coefficients of variation for PMSI, seed yield per plant and PPS 25DAS is also reported by Bhagirath *et al*., (2012) in Indian mustard. PPS 25DAS (0.82, 84.47), PPS 10DAS (0.81, 64.82), PWRCL (0.65, 48.56) and PRWC (0.61, 31.66) had high heritability estimates coupled with high genetic advance suggesting these traits were under of additive gene action. The significant co-efficient of correlation between seed-yield and physiological traits ranged from 0.334* to 0.953**. The seed yield per plant had significant positive correlation with percent relative water content (r=0.407**), at the same time the percent water retention capacity of leaves was significantly positively correlated with percent membrane stability index (r= 0.486*). Our present findings are in agreement with the earlier studies on Indian mustard (Bhagirath *et al*. 2012 and 2014). By physiological variability and association analysis it was concluded that percent population survival at 25 days after sowing, percent relative water content and percent water retention capacity of leaves are major physiological factors in selecting high yielding Indian mustard genotypes under heat stress situation.