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Registration of plant genetic resources in India – A review

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ABSTRACT

Plant genetic resources (PGR) are building block for genetic improvement to develop climate- resilient varieties in agri-horticultural crops. Use of genetic resources depends upon the availability of information and material in public domain to ensure the accessibility of the germplasm to the breeders. While access is of paramount significance, equally important is the recognition of the breeders/researchers who had developed/identified the trait-specific germplasm and establish the ownership of the same in view of Intellectual Property Rights. Indian Council of Agricultural Research has established a mechanism to register the trait-specific germplasm through National Bureau of Plant Genetic Resources to address the above concerns. During last 15 years, about 1 030 accessions of various 186 agri-horticultural crops have been registered so far for particular trait(s). This paper reviews the status trait-specific germplasm registered for major cereals, millets, oilseeds, legumes and vegetable crops by breeders/researchers during last 15 years. While giving brief account on history of PGR registration and trend of registration of germplasm, in-depth analyses were attempted to disseminate the information about trait-specific germplasm available in public domain for use in crop improvement programmes. The information on most-sought-after traits by breeders in various crops were also collected, collated and presented which may be useful to identify and register the new potentially valuable trait-specific germplasm to use the same to develop new climate-resilient crop varieties in future.

Key words: Abiotic stress, Biotic stress, Genetic stock, Plant genetic resources registration, Trait-specific germplasm, Ownership

Plant genetic resources (PGR) are the building blocks for genetic improvement of cultivated crops to develop new varieties. To meet the food requirement of ever-increasing population, the plant breeders are continuously making the efforts by developing the new varieties through crop improvement programmes. To recognize the contribution of breeders/researchers, Indian Council of Agricultural Research (ICAR) operates the mechanism for identification and recommendation for release of new crop varieties and the Department of Agriculture and Co-operation (DAC), Ministry of Agriculture, provides the mechanism for notification of released varieties by Central Sub-Committee on Crop Standards, Notification and Release of Varieties (CVRC) of agricultural crops. Further, enactment of Protection of Plant Varieties and Farmers' Rights Act (2001) ensures the protection of the Intellectual Property Rights (IPRs) of plant breeders and farmers involved in developing the new varieties to be notified and released.

During the process of germplasm manipulations, research and experimentation to develop superior genotypes for specific or multiple traits, many useful materials are developed. Due to presence of specific or a combination of traits the performance of such material is good, but may not show yield superiority over the existing varieties, therefore, do not qualify for their release and notification. In addition, there are raw germplasm which are identified and developed by scientists (landraces/traditional cultivars, genetic stocks), which have resistance/tolerance to biotic and abiotic stresses, and other useful traits but do not qualify to get released and notified because of poor agronomic performance. These materials belonging to the above categories are novel, unique and distinct with academic, scientific and applied value but may not have a direct commercial value.

Unlike the breeders/developers of released cultivars, scientists associated with the development of unique trait-specific or potentially valuable germplasm and genetic stocks had no mechanism for recognition of their work before 1996. Lack of formal recognition of such useful materials and the role of scientists in development thereof discourages them from sharing the valuable material with other researchers. Consequently, most of such valuable material remains under-utilized or lost once the concerned scientist shifts to another

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assignment/organization. With an important rationale to recognize the efforts of researchers for developing the potentially valuable germplasm and to get the information and such germplasm in public domain for their efficient use by the breeders and researchers, ICAR entrusted the responsibility of registration of plant germplasm to National Bureau of Plant Genetic Resources (NBPGR), New Delhi.

In the present review, an attempt was made to analyze the various traits and crops for which the potentially valuable germplasm have been registered so far and the gap analysis for the trait-specific germplasm in selected important food crops. The analyses will be useful to: (i) generate the awareness of availability and enhance the flow of available unique trait-specific germplasm in National Agricultural Research System (NARS), (ii) assess the availability of trait-specific germplasm for particular crop to utilize the same in NARS for crop improvement, (iii) find out gaps for non-availability of germplasm of economically useful traits in important food crops, (iv) increase the institutional inertia to draw the attention of breeders/developers to fill the above gaps, and (v) develop strategies for identifying new potentially valuable trait-specific germplasm to develop climate-resilient crops for future.

For analyses of data, major food crops were considered, viz. cereals (wheat, paddy, maize, barley), oilseeds (groundnut, soybean, oilseed brassicas), millets (sorghum, pearl millet, barnyard millet, finger millet), grain legumes (pigeonpea, greengram, blackgram, chickpea) and vegetables (solanaceous, cucurbitaceous, malvaceous, leguminous). The traits were categorized into six major categories biotic, abiotic, quality, nutritional, breeding and agronomic. Information and data used in analyses of this paper are available in the records of germplasm registration in Division of Germplasm Conservation, NBPGR, New Delhi. Information on registered germplasm published in *Indian Journal of Plant Genetic Resources, Seed Research* and *Annual Reports* and *Newsletters* of NBPGR was also used for confirmation or analyses of the data. Concerned experts and senior crop-specific breeders from leading ICAR crop-based institutes and State Agricultural Universities (SAUs) in NARS were consulted. A minimum two and maximum of 14 breeders for a given crop were contacted to collect the information about the requirement of trait-specific germplasm through mail/ electronic mail and personal discussion for the requirement of desired traits-specific germplasm of important crops to incorporate in their breeding programmes. To obtain the information on above aspects, documented literature (Dhillon *et al*, 2004 2005, 2006 and references therein) was also referred to identify the desired economically useful traits in important crops. Thus, such information was collected, collated and analysed to assess the gaps in the registered trait-specific germplasm available in the public domain through registration and conservation in National Genebank or not (please note that other unregistered trait-specific germplasm available in National Genebank was not considered for this study). Documented literature was also surveyed and the relevant information was extracted for cereals – wheat (Singh *et al*. 2006), paddy (Siddiq *et al*. 2006), maize (Dhillon *et al*. 2006), barley (Verma *et al*. 2006); oilseeds groundnut (Bandyopadhyay *et al* 2004), soybean (Tiwari *et al*. 2004), oilseed brassicas (Kumar *et al*. 2004); millets – sorghum (Elangovan *et al.* 2006), pearl millet (Gupta and Bhatnagar 2006), barnyard millet, finger millet, Small millet (Seetharam *et al*. 2006); grain legumes – pigeonpea (Singh *et al*. 2006), greengram and blackgram (Singh *et al*. 2006.), chickpea (Kumar and Dua. 2006) and vegetables – solanaceous (Kalloo *et al*. 2005), cucurbitaceous (Sirohi *et al*. 2005), malvaceous (Dhankar *et al*. 2005), leguminous (Singh *et al*. 2006). The requirement of trait-specific germplasm was assessed and discussed on the basis of availability of a particular registered material in order to sensitize the breeder/researchers/developer to identify such material with trait(s) in a particular crop and if available, to get that registered. Such germplasm available in public domain, which will be very useful in crop improvement programme to develop the climate-resilient varieties in future.

HISTORY AND EVOLUTION OF PGR REGISTRATION IN INDIA

Plant germplasm registration is an important mechanism to publish, describe and recognize accomplishments of the scientists/researchers responsible for developing trait-specific unique germplasm. This facilitates the availability of the information in public domain, which has become an urgent requirement for safeguarding the national resources from Intellectual Property Rights (IPRs) point of view. The ICAR constituted a committee to suggest guidelines for identification and registration of potentially valuable germplasm. The recommendations of the committee were approved by the ICAR for implementation vide ICAR office order No. 24(2)/ 96-F.C.H/Seed dated 24 March 1996 with Deputy Director General (Crop Sciences) as the Chairman of Plant Germplasm Registration Committee (PGRC), to register such potentially valuable germplasm. NBPGR was identified as the nodal agency for implementation of plant germplasm registration system in India.

In 1996, the detailed guidelines and the proforma for the registration were formalised for major food crops. In 1998, first time proposal for registration was received from private sector and new crop groups, i e medicinal and aromatic plants, agro-forestry species, forage and soil-conserving plants were added to the list of crops that can be registered. In the same year, it was also decided that the exotic germplasm can be registered for a trait identified by a breeder/developer during trails/experiments other than for which it has been imported (*Proceedings of III*rd *Meeting of PGRC*, 10 December 1998). Subsequently in 1999, the revised draft of the guidelines was approved and committee recommended

that the views of the concerned Project Director/Project Coordinator should be sought regarding the germplasm registration proposals so that the authenticity and real worth of the material can be verified by the concerned experts (*Proceedings of IVth Meeting of PGRC*, 18 May 1999). In 2001, the committee suggested that the certificates should be issued to the developers (*Proceedings of VIIth Meeting of PGRC*, 29 January 2001) and the information on germplasm registered be published in the form of 1–2 pages short note authored by the developer(s) of the proposal. The short note should be prepared on the pattern of *Crop Science Journal* and published in *Indian Journal of Plant Genetic Resources* (*Proceedings of VIth Meeting of PGRC*, 10 May 2000). Subsequently, an important decision was taken in 2002, that in addition to the crops mentioned in Annex I of The International Treaty on Plant Genetic Resources for Food and (ITPGRFA) (http://www.planttreaty.org), the priority should be given to crops not being included in the list of species such as groundnut, sugarcane and soybean in field crops and among the horticultural and floriculture crops for which India is an important centre of diversity. The crops agreed upon were: fruits: (mango, citrus, cashew nut, litchi, *ber*, guava, pomegranate), minor fruits: (bael, phalsa, *jamun, anola*), ornamentals: (orchids, bougainvillea, gladiolus), spices and condiments: (black pepper, cardamom, turmeric, ginger), vegetables: cucurbitaceous, solanaceous, leguminous and medicinal and aromatic plants (*Proceedings of XIth Meeting PGRC*, 22 May 2002). In 2004, the clause for the revocation of registered germplasm was added to the guidelines, making provision for de-registration of germplasm which fail the validation test (*Proceedings of XIII Meeting of PGRC*, 23 December 2004). In 2005, crop-based institutes were asked to constitute germplasm identification committees to forward only the authenticated proposals to PGRC (*Proceedings of XIV Meeting of PGRC*, 11 August 2005).

With implementation of registration of germplasm procedures, total 24 meetings of Plant Germplasm Registration Committee have been held till December 2011 and about 2 546 proposals were considered so far. Out of 2 546 proposals, 1 030 potentially valuable germplasm/ genetic stocks have been registered belonging to 186 crop species. The procedure for identification and registration of germplasm of crop plants was developed. The guidelines for registration of germplasm are available at NBPGR website http://www.nbpgr.ernet.in/download/registration.pdf. The information about registered germplasm was earlier published in *NBPGR Newsletter, ICAR Newsletter, Seed Research Newsletter* (Plant Germplasm Registration Notice. 2003, 2006), bulletins (NBPGR 2006, Kak *et al*. 2009, Kak and Tyagi 2010), one-page note were also published in *Indian Journal of Plant Genetic Resources* (an official publication of Indian Society of Plant Genetic Resources, New Delhi) to disseminate information among scientists/users (Singh 2002, 2003a, 2003b, 2004, 2005, 2006; Singh *et al*. 2007; Kak and Srinivasan 2008; Kak and Tyagi 2009, 2010, 2011). An interactive database of registered germplasm is also available at NBPGR website (http://www.nbpgr.ernet.in/ IRCG%20Search/index.htm)

A registration may be repealed to the PGRC in case of false claim(s) or disputed IPR claim. Appeal for counter claim, if any, should reach the PGRC within a period of three months after the publication of notification in *Indian Journal of Plant Genetic Resources.*

TRENDS IN REGISTRATION OF PLANT GERMPLASM

During last 15 years, the trend of registration of the germplasm has been inconsistent. Initially, the less number of proposals were received and successfully registered during first 5–6 years (Fig 1); generally, 7.5 to 51% of proposal qualified for registration in different years. Subsequently, systematic approach was adopted by generating the awareness about the importance of registration of germplasm through Annual Workshops of All India Co-ordinated Research Project on various crops, seminars, symposia, and other related meeting of breeders/researchers. Consequent upon which, not only the number of proposals increased but rate of successful registration of germplasm was also increased appreciably in 2003 and 2004 (Fig 1), however, it was decreased again between 2005 and 2007. Considering total number of proposals submitted (2 546) and number of germplasm registered (1 030) till December 2011, 56% proposals submitted by ICAR crop-based institutes, followed by 30% by SAUs. Some 5% proposals belonged to NBPGR alone. It is to be noted that a very few germplasm accessions were registered by private sector (1%), though most likely the potentially valuable trait-specific germplasm is available in plenty with private sector also (Fig 2). It is evident that vigorous efforts made to publicise the information on registration during important scientific meetings and increased frequency of PGRC meetings, the rate of qualifying germplasm for registration also increased, e g during first seven years (1997–2003), out of 920 proposals only 280 (~30%) qualified for registration, however, during later eight years (2004–11) out of 1 626 proposals, 750 (~46%) germplasm qualified indicating about 16% increase in the rate of successful registration. The trend of registration of germplasm increased gradually since 2008, this dramatic increase is attributed to the publicity and generating awareness about registration mechanism to the researchers of SAUs and also ICAR crop-based institutes. Increased frequency of PGRC meetings also played significant role to increase the registration of germplasm.

Assessment of the availability of registered trait-specific germplasm in genebank (public domain) in important food crops, e g cereals (wheat, paddy, maize, barley), oilseeds (groundnut, soybean, oilseed brassicas), millets (sorghum, pearl millet, barnyard millet, finger millet), grain legumes

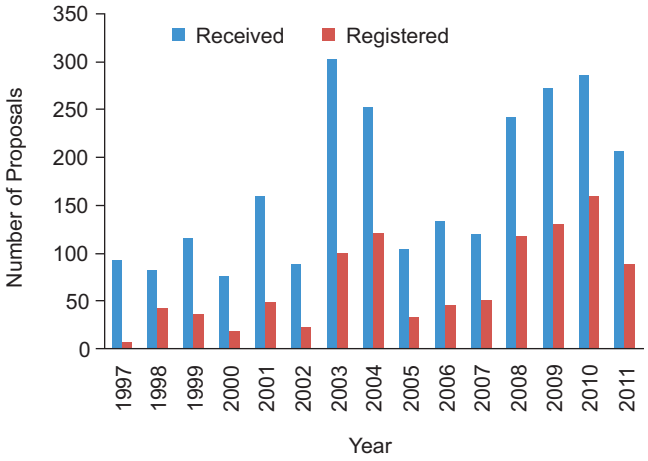

Fig 1 Year-wise number of plant germplasm registration proposals received and registered

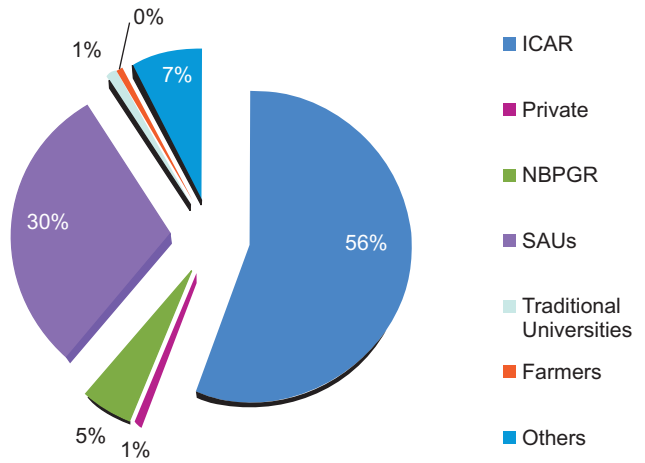

Fig 2 Contribution of various organizations in registration of potentially valuable plant germplasm

(pigeonpea, greengram, blackgram, chickpea), vegetables (solanaceous, cucurbitaceous, malvaceous, leguminous) was carried out. About 60% of registered germplasm belongs to major food crops like cereals, oilseeds and grain legumes. Maximum number of registered germplasm (367) belongs to cereals; of those 147 germplasm were registered for wheat, followed by paddy (112). Some 14% and 11% registered germplasm belongs to oilseeds and grain legumes, respectively (Fig. 3). Generally, in most of the cereal crops, maximum germplasm was registered for biotic stresses, followed by breeding traits (Fig 4). Similar trend was observed in millet crops also (Fig 5). With regard to oilseed crops, maximum number of germplasm was registered, generally, for quality traits in oilseed brassicas but for groundnut and castor it was again for biotic stress (Fig 6).

For the ease of understanding, we discussed registered germplasm of various major crops under cereals, oilseeds, millets, grain legumes and vegetable crops. The traits for

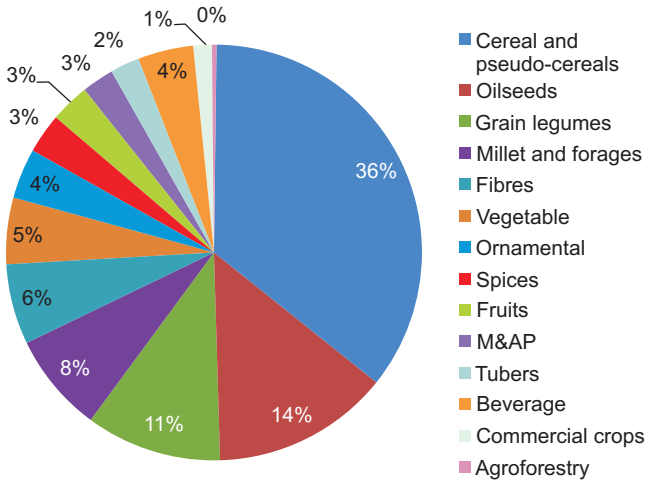

Fig 3 Crop-group-wise presentation (%) of germplasm registered

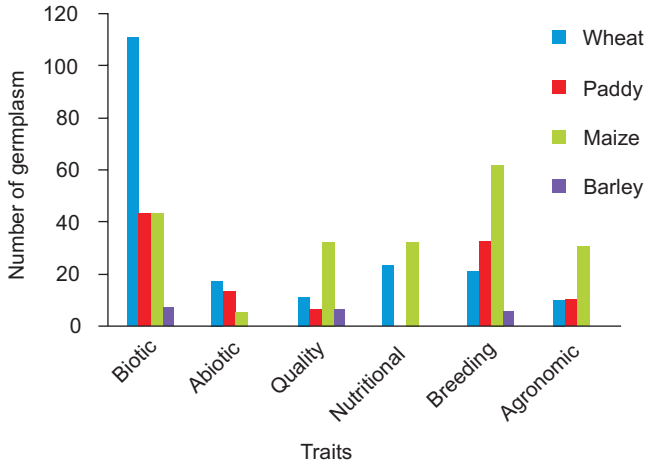

Fig 4 Status of trait-specific germplasm registered in major cereal crops

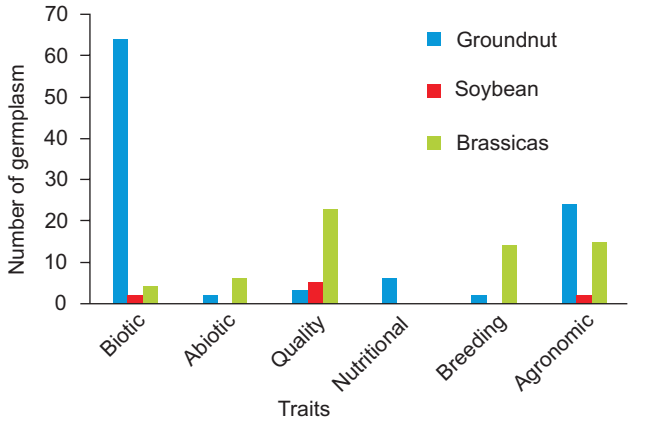

Fig 5 Status of trait-specific germplasm registered in major oilseed crops

which the germplasm was registered were also categorised into six major categories, viz. biotic, abiotic, quality,

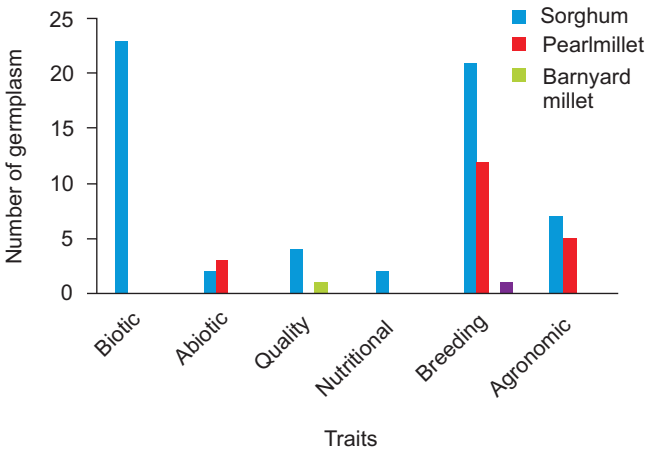

Fig 6 Status of trait-specific germplasm registered in millet crops

nutritional, breeding and agronomic traits. Crop group-wise analyses are presented in following sections.

Cereals

Generally, in most of the cereals, maximum germplasm was registered for biotic stresses, followed by breeding traits (Fig 4). Amongst the cereals, about 111 germplasm were registered for biotic stresses mainly for brown, black, yellow rusts, Karnal bunt, powdery mildew, hill bunt, loose smut, leaf blight in wheat, followed by paddy (43) for gall midge, Rice Tungro Virus, bacterial blight, leaf and neck blast, plant hoppers and maize (41) for madyis leaf blight, sorghum downy mildew, banded leaf sheath, post flowering stock rot (Fig. 4). Compared to biotic stress only few germplasm (31) were registered for abiotic stresses in all the major cereals considered together.

In wheat, large number of germplasm were identified and registered as tolerant to rust by Indian Agricultural Research Institute (IARI) New Delhi; for powdery mildew, loose smut and Karnal bunt mainly by Directorate of Wheat Research (DWR), Karnal and Punjab Agricultural University (PAU), Ludhiana. Central Soil Salinity Research Institute (CSSRI), Karnal, was proactive in registering the salinity and alkalinity-tolerant (2) germplasm and Dr Punjab Rao Deshmukh Krishi Vidyapeeth (PDKV), Akola, developed and registered heat (1) and drought-tolerant (1) germplasm of wheat. Rice, being a major staple food crop, drew attention of rice researchers increasingly. A good number of cytoplasm male sterile lines (28) have been registered mainly by Directorate of Rice Research (DRR), Hyderabad, IARI and Balasaheb Sawant Konkan Krishi Vidypeeth (BSKKV), Dapoli. Some 17 germplasm have been registered for resistance to various biotypes of gall midge by DRR and Indira Gandhi Krishi Vishva Vidyalaya (IGKVV), Raipur.

For biotic (41), abiotic (5), quality traits (32), nutritional (32), breeding (62) and agronomic traits (24) and yield contributing traits (6) germplasm were registered in maize mainly by Directorate of Maize Research (DMR); Chaudhary Charan Singh Haryana Agricultural University (CCS HAU), Ucchani, Karnal and Acharya NG Ranga Agricultural University (ANGRAU), Hyderabad. The registered germplasm include the accessions for resistance to major fungal diseases in maize, however, for brown stripe, downy mildew and charcoal rot which are also economically important diseases and no germplasm has been registered so far for tolerance to above diseases. For high tryptophan (10) by Vivekanand Parvatiya Krishi Anusandhan Sanasthan (VPKAS) and DMR; high sugar content (8), high popping (2) and high oil content (2) by DMR are notable accessions which were registered for nutritional traits. In barley, rust resistant germplasm were registered by IARI (1), DWR (1) and CCS HAU (2). Some four genic male sterile lines were also registered by CCS HAU in barley. For better malting quality, four germplasm were registered by DWR. There is need to draw the attention of the researchers to identify the germplasm for tolerance to terminal heat, drought and salinity as these are most desired traits from breeding point of view to develop the new varieties to mitigate climate change.

Oilseeds

As far as oilseeds are concerned three crops – groundnut, soybean and oilseed brassicas were considered for present analysis. It is evident from the Fig 5 that groundnut, being a major oilseed crop in India, remained in focus as far as germplasm registered for biotic, nutritional and agronomic traits are concerned. In groundnut, 46 germplasm have been registered for tolerance to biotic stress mainly for stem rot, rust, peanut bud necrosis, leaf spot and thrips mainly by Directorate of Groundnut Research (DGR) (Formerly National Research Centre on Groundnut, Junagadh) and University of Agricultural Sciences (UAS), Dharwad. Two germplasm lines have been registered for tolerance to iron cholorosis each by DGR, Junagadh and PDKV, Akola. High oil and protein content germplasm have also been registered in groundnut by DGR. There is a need to draw the attention of the groundnut researchers to develop the material for tolerance to soil-borne disease (root and collar rot), peanut stem necrosis, root knot nematode and leaf miner which are the much-sought-after germplasm with above traits by the groundnut breeders. Also, germplasm with drought, cold, heat and salinity tolerant were also not registered in groundnuts which are again most desired traits by the groundnut breeders. Oilseed brassicas are another important group of oilseed crops. Greater attention is required for oilseed brassicas as far as abiotic and biotic stresses are concerned (Yadava *et al.* 2011). Only three germplasm accessions were registered mainly for tolerant to white rust, *Alternaria* blight the most economically important diseases in mustard, a few germplasm (6) for terminal heat tolerance by Directorate of Rapeseed-Mustard Research (DRMR), Bharatpur (*see* details of registered germplasm by DRMR in Chauhan *et al.* 2011) and salinity tolerance by CCS HAU

were also registered. Quantity and quality of oil is important aspect for oilseed brassicas; about 23 germplasm were registered mainly for high oil content by DRMR, low erucic acid by Tata Energy Research Institute (TERI), New Delhi, and low glucosinolate content by Nagpur University, Nagpur. Developement of double low *B. juncea* will continue to be the focus in coming years (Chauhan *et al.* 2011). Tolerant to *Sclerotinia* rot, drought, heat (at seedling stage) and high linolenic acid (for industrial purpose) are important traits desired by the breeders and the germplasm with above traits were not registered so far in oilseed brassicas. In other oilseed crops like soybean, linseed, sunflower, there is a need to develop the germplasm for drought, heat, cold and salinity tolerance. For improving the quality of soybean low/null lipoxygenase, high oil content and *Tofu* making traits are also equally important that need the attention of the researchers. In soybean, high oleic and linolenic acid (1) and trypsin inhibitor with early maturity are the notable traits which have been identified and registered by Directorate of Soybean Research (DSR), Indore. In other oilseeds crops, not much progress is made to identify the germplasm for registration for desirable traits.

Millets

Millets are the promising crops from the view point of climate resilient agriculture. Except sorghum, not much trait-specific germplasm was identified and registered. Fig 6 presents the status of trait-specific germplasm registered in millets. In sorghum, germplasm accessions were registered with resistance to grain mould (24), shoot fly (3), and aphid (1), and other foliar diseases (6) by Directorate of Sorghum Research (DSR), Hyderabad. Whereas germplasm with tolerant to stem borer, shoot bug, ear head bug and salt are not available which are desirable traits from breeding point of view. However, in sorghum, there are 21 male sterile lines registered so far mainly by DSR, Hyderabad. Importantly, eight germplasm for male sterility and two for fertility restorers were identified and registered in pearlmillet by CCS HAU. No other germplasm in pearlmillet was registered for the traits like, tolerant to salinity and lodging, tolerant to purple stem disease, compact ear head and bold grain type which are considered important by pearlmillet breeders. In barnyard millet and foxtail millet, which are the crops for future only two germplasm lines have been registered for easy de-hulling type and genic dwarfness, respectively, by VPKAS, Almora. None of the germplasm was registered for biotic, abiotic, and nutritional traits or yield traits in these two crops although, many germplasm with useful traits are likely to be available with breeders.

Grain legumes

Legumes are the main source of protein in diet of Indian

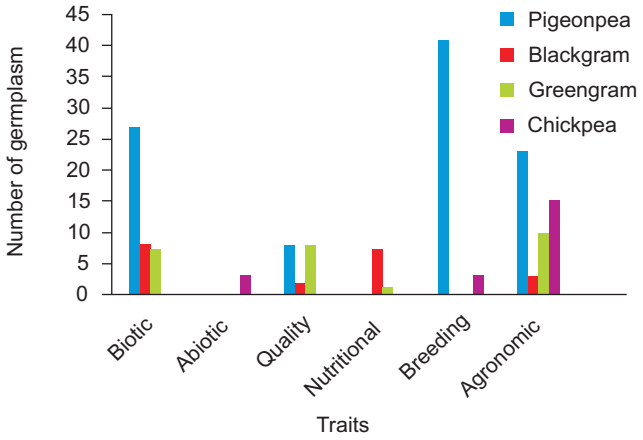

Fig 7 Status of trait-specific germplasm registered in major grain legume crops

population. Being the main sources of protein, pigeonpea, blackgram, greengram and chickpea were selected for present analysis. Amongst the selected crops, pigeonpea is the most important and has drawn the attention of researchers, as most of the germplasm registered belong to the pigeonpea (Fig 7). Some 27 germplasm tolerant to biotic stress (sterility mosaic disease, *Fusarium* wilt, *Phytophthora* blight and pod fly) were registered in pigeonpea by Indian Institute of Pulses Research (IIPR), Kanpur and Gujarat Agricultural University (GAU). Fourteen fertility restorers - seven each by GAU and Sardarkrushinagar Dantiwada Agricultural University (SDAU), Sardarkurshinagar were registered in pigeonpea. Tolerant to pod borer, drought, waterlogging, sodicity, cold and terminal heat are the traits for which the germplasm need to be identified and registered. In blackgram, eight for biotic stresses and in greengram seven germplasm for biotic stresses were developed and registered by G B Pant University of Agriculture and Technology (GBPUA&T), Pantnagar. Good germplasm have been developed in pigeonpea for quality traits (8) by GBPUA&T and germplasm with unique trait for breeding (41) and agronomic (22) point of view by IIPR, SDAU, GAU and GBPUA&T. Except in chickpea (one accession for salt tolerance by CSSRI, Karnal), no other germplasm was registered for abiotic stress tolerance in any of the above legume crops. Cold, heat, drought, terminal heat tolerance, salinity, lodging, water logging are main traits which needs the attention of researchers to develop the germplasm in legume crops. Tolerant to leaf miner, seed beetle, *Ascochyta* blight, *Fusarium* wilt, root-knot nematode, cyst nematode in chickpea; pod borer in pigeonpea and bruchid in black gram and green gram are other important traits where no germplasm is registered so far by any researcher.

Vegetables

Relatively a very few germplasm were registered for unique traits in vegetable crops, though it is an economically

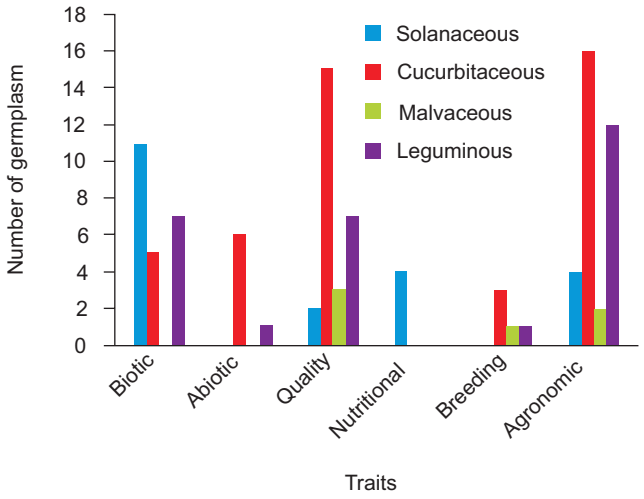

Fig 8 Status of trait-specific germplasm registered in vegetable crop groups

and nutritionally important group of crops. (Fig 8). Brinjal, tomato and chilli (Solanaceous), gourds (*Cyclanthera pedeata, Cucurbita moschata, Cucumis melo* var. *mormordica, Coccinia grandis, Momordica charantia, Luffa cylindrica*), cucumber (*Cucumis sativus*) and melons (*Citrullus lanatus, Cucumis melo* var. *momordica*) (Cucurbitaceous), okra (Malvaceous), pea, fenugreek (Leguminous) were considered for present study. NBPGR, Indian Institute of Horticultural Research (IIHR), Bangalore; Indian Institute of Vegetable Research (IIVR), Varanasi and Central Institute for Arid Horticulture (CIAH), Bikaner, were the main organizations for registration of vegetable germplasm. Mostly brinjal germplasm were registered for tolerance for bacterial wilt disease by IIHR. A total of eight tomato germplasm registered – three for tolerance to root-knot nematode by CCS HAU and NBPGR, one each for high lycopene, carotene and total soluble sugars by IIVR and NBPGR. In tomato, tolerance to anthracnose, early blight, *Fusarium* wilt, tomato mosaic virus (strain 1, 2, 3, 4) and leaf curl virus germplasm need to be identified and registered to use in breeding programme. As far as abiotic stress are concerned, tolerance to heat, drought, cold and salinity are considered the most important traits by the tomato breeders. In chilli, 14 germplasm lines were registered, of which nine were fertility restorers/cytoplasmic male sterile and three were for tolerance to leaf curl virus, thrips, and mites, and thrips and powdery mildew. In okra, germplasm for tolerance to waterlogging, drought, high and low temperature, salinity, yellow vein mosaic virus, wilt, powdery mildew, leaf hopper, borers and red spider mites are the important traits which need the attentions of researchers to develop/identify the germplasm with above traits. Okra needs utmost attention for identifying the germplasm for major biotic and abiotic traits as none of the germplasm registered for above traits. Most of the germplasm in cucurbitaceous crops were registered either for quality traits or agronomic traits. A few germplasm was registered for biotic (5) and abiotic (6) also. Tolerant to powdery mildew, cucumber mosaic virus, zucchini mosaic virus, water melon mosaic virus, fruit fly and nematode are generally the common problem in cucurbitaceous crops which needs greater attention as suggested by breeders and documented in literature. Amongst the legume vegetables, fenugreek and peas were considered. Four germplasm - two each for downy and powdery mildew resistance by CCS HAU and one each for powdery mildew resistance were registered by IARI and GBPUA&T. In addition to above, some other germplasm belonging to ornamentals (4%); spices, fruits, M&AP (3% of each of crop group total germplasm registered) and tubers, beverages and other commercially important crops (2% each) were also registered (Fig 3).

CONSERVATION, MULTIPLICATION AND DISTRIBUTION OF REGISTERED GERMPLASM

Registered germplasm is conserved either in National Genebank (in form of seeds) or at designated crop-based National Active Germplasm Site (NAGS) (especially vegetatively propagated crop germplasm) depending upon the type of the propagule. National Genebank at NBPGR is responsible for long-term conservation of orthodox seed material accompanied by passport and genebank-related information. Untreated seed material received as prescribed seed quantity (minimum of 2 000 seeds for self-pollinated and 4 000 seeds for cross-pollinated crops) for registration are subjected to seed health testing for ensuring the germplasm free from quarantine pests (NBPGR, 2005, Guidelines for Registration of Plant Germplasm; http://www.nbpgr.ernet.in/download/registration.pdf.). Unique National Identity or IC Number (Indigenous Collection), subject to qualifying the international genebank standards (FAO, Draft revised genebank standards for conservation of orthodox seeds 2011), are assigned. After testing of germination following International Seed Testing Association (ISTA 1993) standards the moisture content of the seeds is equilibrated to 5–7% in the walk-in-drying room (15°C and 15% RH), the seeds are heat-sealed with the help of a vacuum sealer in tri-layered aluminium foil packets, labelled and stored at –18°C in National Genebank. However, the standards are relaxed for seeds of difficult species, e g wild, rare and endangered species on case-to-case basis. Recalcitrant seed and vegetatively propagated crop germplasm are deposited in the field genebank of the concerned crop-based NAGS (http://www.nbpgr.ernet.in/download/registration.pdf.) for conservation and a certificate to this effect has to be obtained by the developer before the material is proposed for registration. It is obligatory on the part of developer and developing organization to maintain the stock of registered germplasm to share the germplasm in NARS. Active or working collection(s) may also be maintained by the NAGS with a responsibility for its multiplication and distribution to

bona fide users in the NARS. NBPGR regularly organize the Germplasm Field Days for displaying the germplasm variability of various crops in the field to select the genotype by the breeders of their interest. The registered germplasm accessions of different crops are displayed at suitable locations including in the field genebanks of regional stations of NBPGR located strategically in various agro-climatic regions. Concerned crop breeders select the material and the same is distributed to the breeders to meet their requirement under material transfer agreement (http://www.nbpgr.ernet.in/download/SMTA.pdf). The users can indent the germplasm including registered ones of their interest available in NBPGR (http://www.nbpgr.ernet.in/download.htm).

The main purpose of plant germplasm registration is dissemination of information, including identity, pedigree, important traits of the registered germplasm so that the breeders and researchers could use this information and trait-specific germplasm in developing new varieties. The total 1 030 accessions with unique traits have been registered so far belonging 186 agri-horticultural crops. Analyses indicated that there are many important traits in major food crops where the attention of the researchers needs to be drawn to identify and register the trait-specific germplasm to use the same by breeders in crop improvement programmes. Although, NBPGR has made tremendous efforts to publicise it, nevertheless, there is ample scope for proposing the germplasm for registration, particularly the elite material identified through AICRP trails and do not qualify to be notified and released by CVRC for one reason or the other. Such material may be registered for a particular unique or yield-contributing trait(s) which contribute maximum for high yield subjected to qualifying criteria. For example, a material or an entry of mustard in advance trails is ranked second in yield and not qualified for release and notification by CVRC. In this entry, if the higher yield is attributed to the fact that significantly higher number of primary branches and number of pods clusters, such material can be registered for the above agronomic trait. It is all the more important as the concerned breeder may or may not take due care to maintain above type material for future use in crop improvement programmes once a variety did not qualify for release. Registering such germplasm will help to (i) assign the ownership to developer/breeder, (ii) document the information and make it available in public domain, (iii) conserve in genebank, and (iv) to distribute it for further utilization by other breeders.

We have attempted to collect the information from concerned crop breeders, published research papers and other documented literature about the most desired traits of breeders' interest in respective crops. Also, we compared and discussed about the germplasm with specific traits in given crops which is not registered so far. However, it does not necessarily mean that the material with the specific traits is not available in NARS or private sector. It is presumed that a large number of trait-specific germplasm is likely to have been developed and available with individual breeder in both public and private sectors, and NGOs also. By virtue of a common practice, each breeder maintains their own lines to use them in their breeding programmes. It is imperative that the breeders make the efforts to get potentially valuable germplasm registered to claim their ownership and place this valuable germplasm and related information in the public domain so that the other concerned breeders may also use that germplasm and benefit accrued by using this germplasm may be shared with the original developers. It will serve the basic intent of developing, registering, conserving, distributing the potentially valuable germplasm and documenting the information to be made available in public domain for further utilization by the breeder to develop the climate-resilient varieties in crops as genetic variability has been playing and will continue to play significant role in mitigating the challenges due to climate change in future.

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