# IMPORTANCE OF PULSES RESEARCH IN INDIA: CHICKPEA AND PIGEONPEA

**Girish Prasad Dixit**

Indian Council of Agricultural Research (ICAR)
- Indian Institute of Pulses Research,
Kanpur 208 024, India

..........................................................................................................................

**GIRISH PRASAD DIXIT** is presently working as Project Coordinator (Chickpea) at Indian Institute of Pulses Research, Kanpur, India with the responsibility to coordinate the Indian chickpea research programme. He obtained M.Sc. and Ph.D. degrees in Genetics and Plant Breeding from Banaras Hindu University (BHU), Varanasi, India and has been working on the genetic improvement of pulse crops at Indian Institute of Pulses Research, Kanpur, India for the last 25 years. He has developed about 10 high yielding varieties of pulse crops which are very popular in India.

# ABSTRACT

Pulses constitute an important dietary constituent for humans and animals because of their richness with proteins and other essential minerals, vitamins and dietary fibres. In India, over a dozen pulse crops are grown in one or the other part of the country, however, the most important pulse crops grown are chickpea and pigeonpea. India has been a leader in production as well as consumption of pulses in the world. The area under pulses cultivation in the country is currently estimated at about 22-23 million hectares while the realized productivity is less than 1 ton per hectare. As a result of rising demand of vegetarian food due to ever-increasing population and diversification of food habits, demand of pulses is increasing at a fast pace. This will be further challenged by changing climate which may manifest itself in the form of shifting rainfall pattern, untimely and erratic rains, extreme temperatures, *etc*. which may also change the cultivation pattern of pulses. Post-harvest losses still remain a matter of great concern. Accordingly, pulses researchers have to remain prepared with a wide range of pulse genotypes which may adapt themselves across changing climates. For developing such genotypes, wild relatives which are rich reservoir of useful alien genes can play an important role. Further improvement in pulses productivity is needed through conservation and diversification of agriculture so as to increase the productivity of the system and improve soil health.

Since pulses are largely cultivated in India under rain-fed and monsoon dependent areas where soil moisture is the critical factor determining the productivity, the production trends keeps fluctuating every year depending upon rainfall. The major constraints that limit the realization of potential yield of pulses include biotic and abiotic stresses prevalent in the pulses-growing areas besides socio-economic factors. Among abiotic stresses, drought and high temperature at terminal stage, cold as well as sudden drop in temperature coupled with fog during the reproductive phase and salinity/alkalinity throughout the crop period inflict major yield losses and instability in production. All these stresses make pulse crops less productive with unstable performance in one or the other way. Thus, there is a strong need to formulate strategic plan to achieve the goal focusing on broadening the genetic base of pulses for breaking yield barriers, hybrid development in pigeonpea, transgenics in chickpea and pigeonpea, high yielding varieties with tolerance to biotic and abiotic stresses, bio-intensification of pulse-based cropping systems and resource conservation, development of micro-irrigation techniques, mechanization and minimizing post harvest yield loss, climate risk management and efficient extension models for dissemination of pulse-based technologies for farmers to make the pulse cultivation productive and remunerative.

**KEYWORDS**

Chickpea, Pigeonpea, Pulses, Varieties, Yield

**REFERENCES**

Dixit, G.P., J. Singh, and N.P. Singh, 2015: Pulses: Challenges & Opportunities under changing climatic scenario. ISPRD, IIPR, Kanpur, p. 347.

Gowda, C.L.L., 2015: Pulses research and development strategies for India. Pulse Handbook-2015, pp.17-33.http://www.commodityindia.com/mailer/Pulses_handbook_2015_E Book.pdf

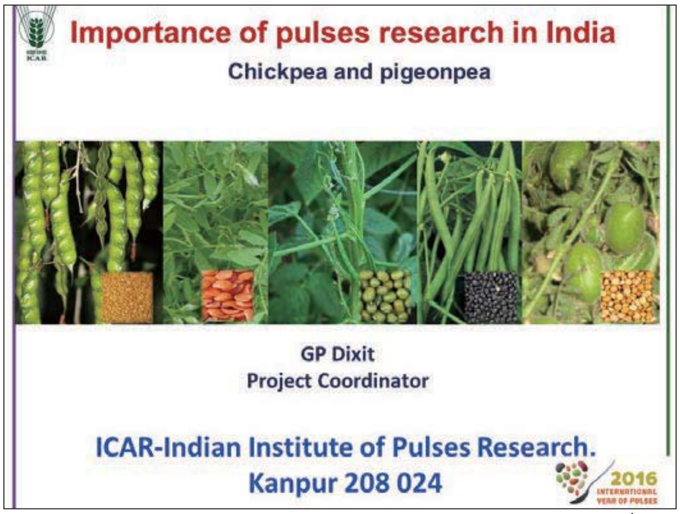
Gaur, P.M., A.K. Jukanti, S. Srinivasan, and C.L.L. Gowda, 2012: Chickpea (*Cicer arietinum* L.). In: Bharadwaj, D.N. (ed.) Breeding of Field Crops. Agrobios (India), Jodhpur, India, pp. 165-194.

Saxena, K.B., R.V. Kumar, A.N. Tikle, M.K. Saxena, V.S. Gautam, S.K. Rao, D. Khare, Y.S. Chauhan, R.K. Saxena, R.K. Varshney, B.V.S. Reddy, D. Sharma, L.J. Reddy, J.M. Green, D.G. Faris, M. Mula, R. Sultana, R.K. Srivastava, C.L.L. Gowda, and S.L. Sawargaonkar, 2013: ICPH 2671 - The world's first commercial food legume hybrid. Plant Breeding 132, 479-485.

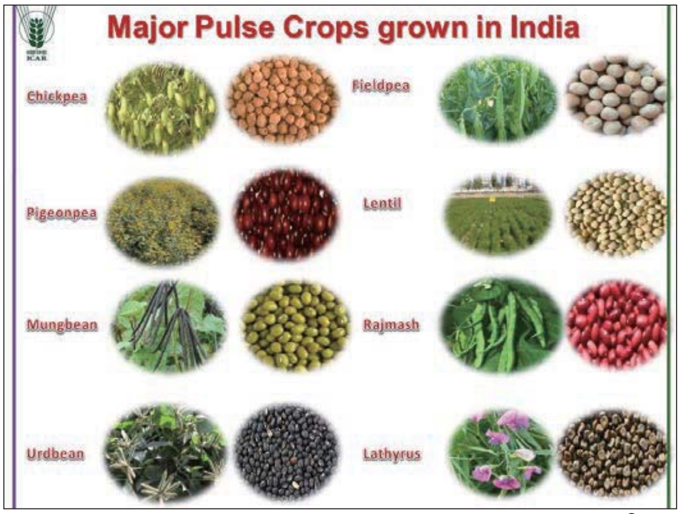
Sharma, H.C., 2014: Climate change effects on insects: implications for crop protection and food security. Journal of Crop Improvement, 28, 229-259.

Singh, N.P. and A. Pratap, 2015: Pulses for nutritional quality and health benefits. In: Singh U., C.S. Praharaj, S.S. Singh, and N.P. Singh (eds.) Biofortification of food crops, Springer India, New Delhi.

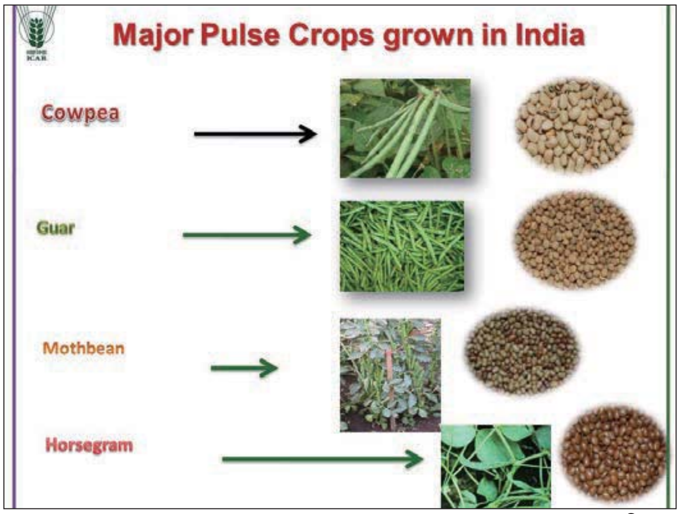
Srivastava, A.K., G.P.Dixit, S.K.Chaturvedi, N.P.Singh, and M. Nissar, 2016: Genetic relatedness among desi and kabuli chickpea varieties of India. Journal of Food Legumes 29, 7-9.



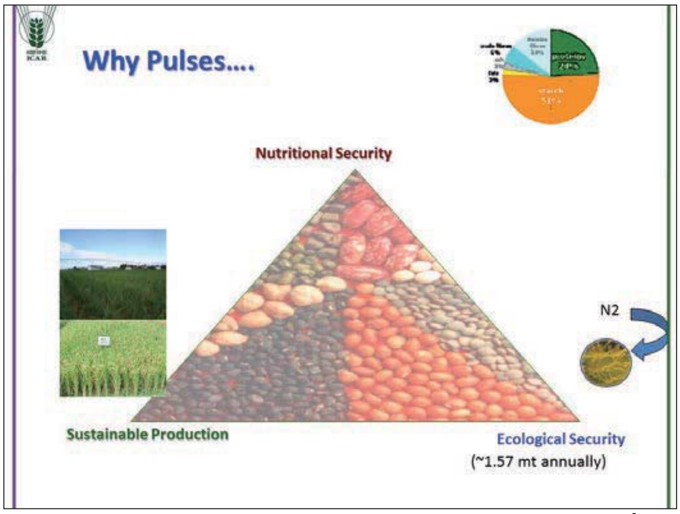

1




2




3

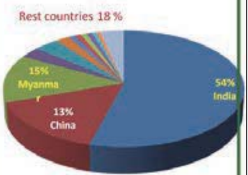



4

## Asian Status: Major Pulse Producing Countries (2013)

| Crops | Area (000' ha) | Production (000' ton) | Yield (Kg/ha) |
|---|---|---|---|
| India | 28170.0 | 18311.0 | 650 |
| Myanmar | 3888.0 | 5236.0 | 1347 |
| China | 2897.0 | 4486.0 | 1548 |
| Pakistan | 1363.0 | 997.0 | 731 |
| Turkey | 892.0 | 1257.0 | 1410 |
| Iran | 800.0 | 718.0 | 897 |
| Korea | 360.0 | 310.0 | 861 |
| Vietnam | 323.0 | 302.0 | 937 |
| Nepal | 297.0 | 314.0 | 1056 |
| Bangladesh | 282.0 | 268.0 | 948 |
| Thailand | 244.0 | 220.0 | 902 |
| Indonesia | 184.0 | 206.0 | 1118 |
| Other countries | 864.0 | 1177.0 | 1362 |
| Total Asia | 40564.0 | 33802.0 | 833 |

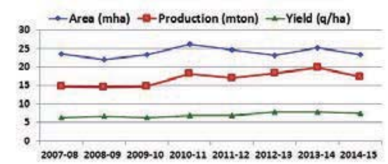
Percentage Share of Different Countries in Asian pulse production

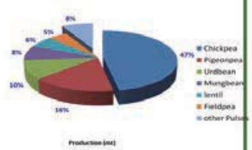



5

## Pulses Scenario

| Items/Years | 2006-07 | 2007-08 | 2008-09 | 2009-10 | 2010-11 | 2011-12 | 2012-13 | 2013-14 | 2014-15 | 2015-16 |
|---|---|---|---|---|---|---|---|---|---|---|
| Area (mha) | 23.19 | 23.63 | 22.09 | 23.28 | 26.28 | 24.78 | 23.47 | 25.21 | 23.55 | 23.50 |
| Production | 142.0 | 147.6 | 145.7 | 147.0 | 182.4 | 172.10 | 183.4 | 190.27 | 172.0 | 164.7 |
| Export | 2.64 | 1.82 | 1.45 | 1.29 | 2.06 | 1.75 | 2.01 | 3.45 | 2.22 | 2.55 |
| Import | 25.04 | 29.45 | 25.8 | 37.64 | 27.80 | 34.96 | 38.36 | 31.78 | 45.85 | 57.98 |
| Total availability | 164.4 | 175.23 | 170.05 | 183.35 | 208.14 | 205.31 | 219.75 | 218.16 | 215.63 | 220.13 |




6

## Issues Affecting Pulses Production

- Low profitability and low productivity as compared to cereals
- Mostly grown in rainfed areas, hence wide fluctuations in production from year to year
- Poor price realization
- Poor seed chain
- Vulnerable to biotic and abiotic stresses

7

## Focus

**Improving yield potential**

- Pre-breeding – utilization of wild relatives & primitive landraces
- Restructuring existing plant types
- Nutrient and water use efficient type

**Maximizing the Realization of yield potential**

- Appropriate agronomic management (in terms of cropping sequence, planting density, water management, biological nitrogen fixation, resource use efficiency)
- Reducing Yield losses (biotic & abiotic stresses)
- Reducing cost of production (mechanization and herbicide resist.)

8

## Major Research Achievements

- Reduction in crop duration in chickpea from 135 to 100 days
- Seed size of *Kabuli* chickpea increased from 35 to 55 g per 100 seed weight
- High input responsive, wilt resistant varieties developed in chickpea
- Heat tolerant and drought tolerant varieties for rainfed area
- Early maturing varieties developed in pigeonpea which fit in multiple cropping
- Hybrid pigeonpea
- Machine harvestable varieties

9

## High yielding varieties of pulses

| | |
|---|---|
| Chickpea | 89 |
| Pigeonpea | 36 |
| Mungbean | 60 |
| Urdbean | 44 |
| Lentil | 22 |
| Fieldpea | 26 |
| Rajmash | 4 |
| Others | 38 |
| Total | 319 |

10

## Chickpea Varieties

| Varieties | Special feature |
|---|---|
| JG 14, JAKI 9218, RVG 202, RVG 203, Rajas, Pusa 547, JG 11, JG 16, Subhra | Short duration |
| MNK 1, PKV Kabuli 4-1, Phule G 0517 (Kripa) | Extra Large seeded Kabuli |
| JG 14 , RVG 202, RVG 203 | Heat tolerant |
| RSG 888, Vijay | Drought tolerant |
| GNG 1581, JG 16, Digvijay, Gujarat Gram 2, BG 391, BGD 78, Ujjawal, GLK 26155, HK 05-169 | Wilt resistant |
| PBG 5, GNG 469, Himachal chana 1 | *Ascochyta* blight tolerant |
| NBeG 47, GBM 2, HC 5 | Machine Harvestable |

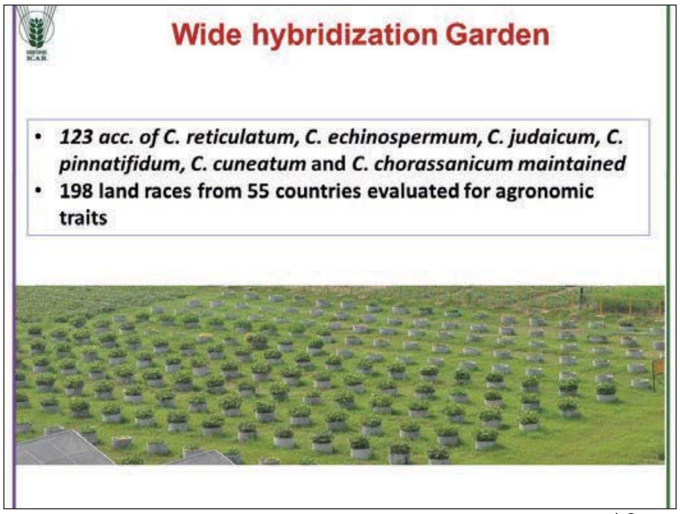
Most popular variety of the decade: JG 11, Vijay, JG 16, GNG 1581, JG 130

11

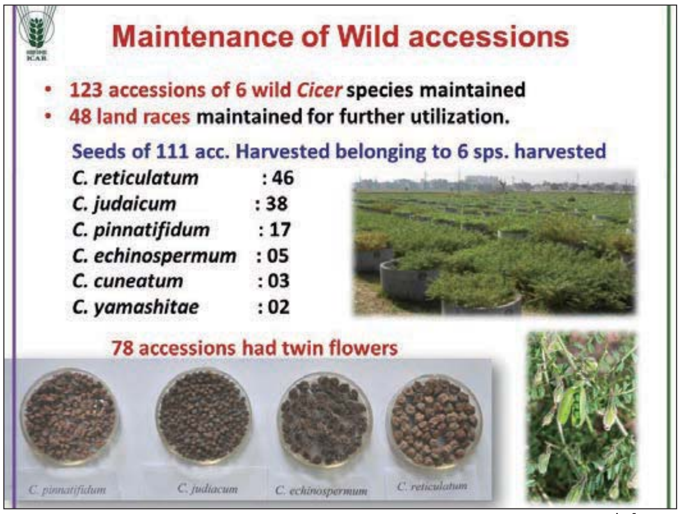
## Genetic Resources

| Accessions | Number |
|---|---|
| Germplasm acc. | 14310 |
| Landraces | 198 |
| Wild sps. Acc. | 126 |
| Total acc. | 14634 |

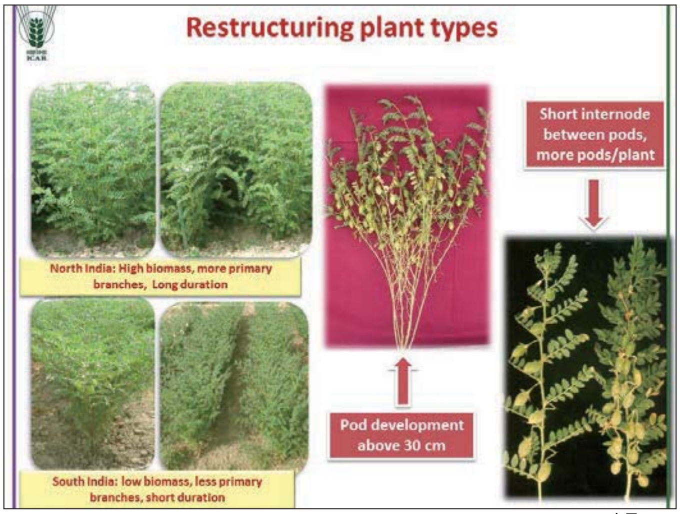
12



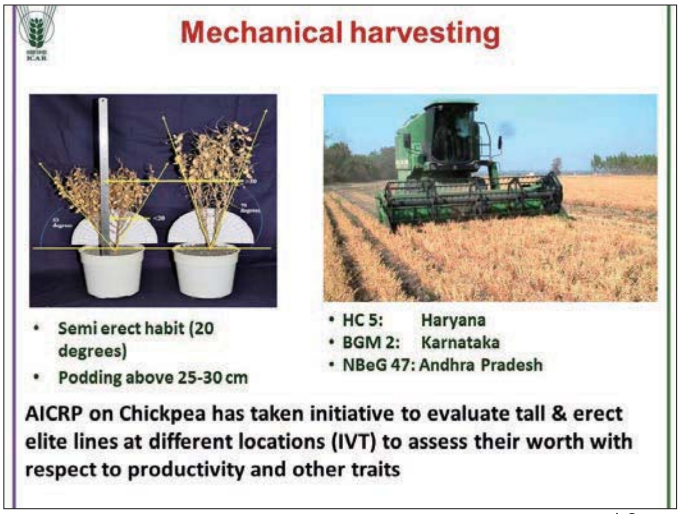

13



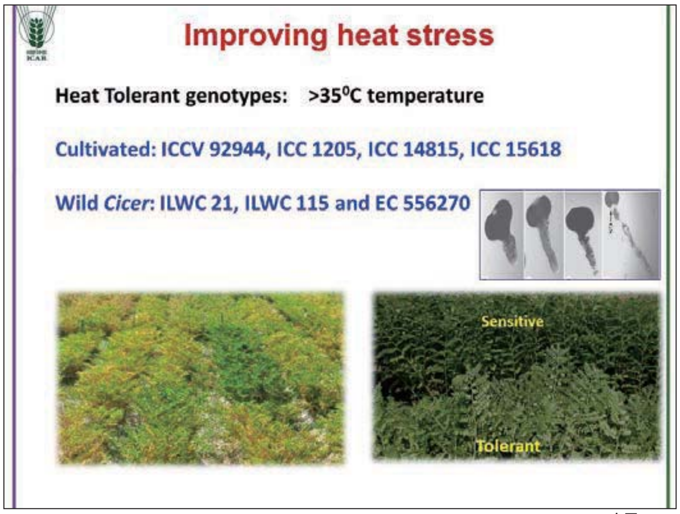

14



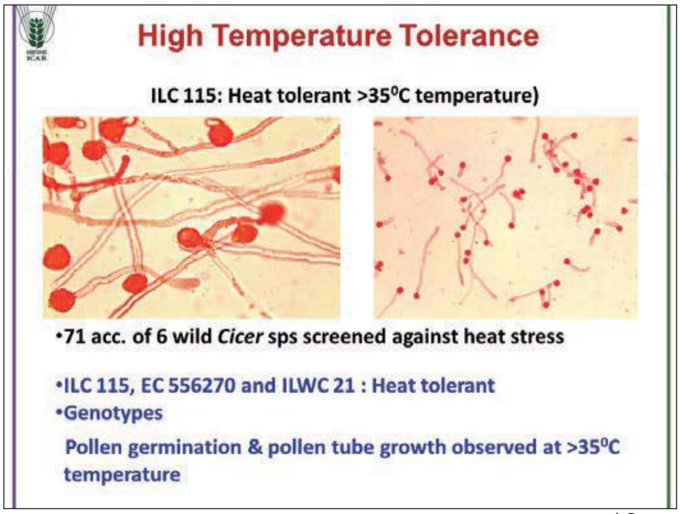

15




16




17




18

## Herbicide Tolerance in chickpea

Genetic variation is present in chickpea germplasm

Will reduce cost of cultivation and human drudgery

Herbicides: Metribuzin and Imazethapyr

**Herbicide tolerant:**
ICC 1161, ICC 1205, ICC 13816, IPC 2008-29, IPC 2006-134, ICC 1710, ICC 2629, IPC 2010-56 & IPC 2010-173

19

## Varieties with enhanced phosphorus use efficiency

Since phosphorus (P) fertilizers are becoming very expansive or even many times not available for pulses, there will be need to develop varieties with enhanced 'P' use efficiency.

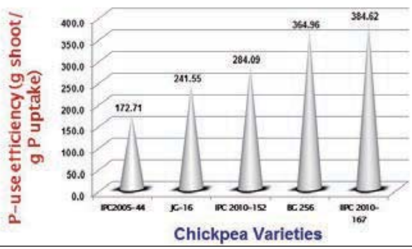
20

## P-use Efficiency in chickpea

Reduction in plant biomass due to low P availability in soil varied from 10 to 80% among the genotypes.

Better P use efficiency was observed in BG 256, IPC 2010-167

Presence of genetic variations for P use efficiency observed.




21

## Rapid Generation advancement

IIPR Off-Season Nursery, UAS Campus, Dharwad

22

## Pigeonpea Varieties

| Varieties | Special feature |
|---|---|
| Maruthi, Asha, BDN 2, BSMR 736, MA 6 , Vipula, | Wilt resistant |
| Bahar, BSMR 736, Asha, Sharad, Pusa 9 , IPA 203 | Sterility Mosaic Disease |
| Asha, BSMR 736, BSMR 853, Rajeev Lochan, BDN 711 | Wilt and SMD |
| JKM 189 | Drought tolerant |
| GTH-1 | Hybrid |
| BRG 4 | Suitable for both timely and delayed sowings |

Most popular variety of the decade →

| | |
|---|---|
| UPAS 120 | Early |
| Bahar | Late |
| Narendra Arhar 1 | Late |
| Asha (ICPL 87119) | 1993 |
| Maruthi (ICPL 8863) | 1985 |

23

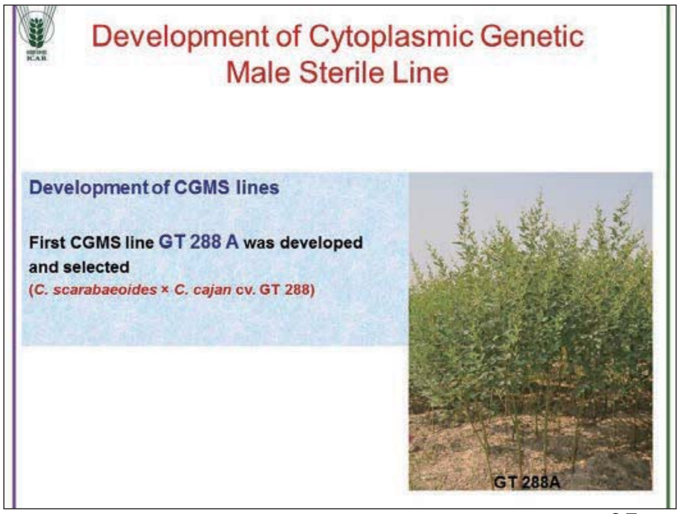
## Priority Research Areas for Enhancing Pigeonpea Productivity

Development of hybrids in pigeonpea

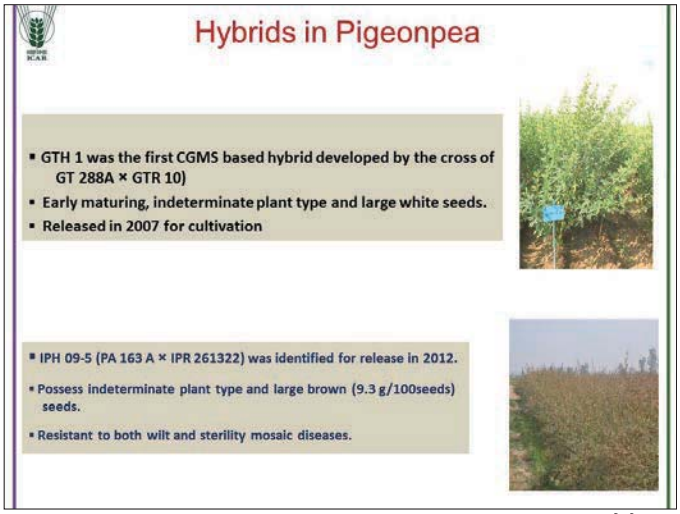
- ✓ To introgress CMS and fertility restoring genes into disease resistant and locally adapted lines
- ✓ Study of stability of CMS and fertility restoration systems,
- ✓ Genetic enhancement of parental lines and selection of right combination of parents i.e. parents which are most diverse and possess good combining ability.

Sterile Fertile

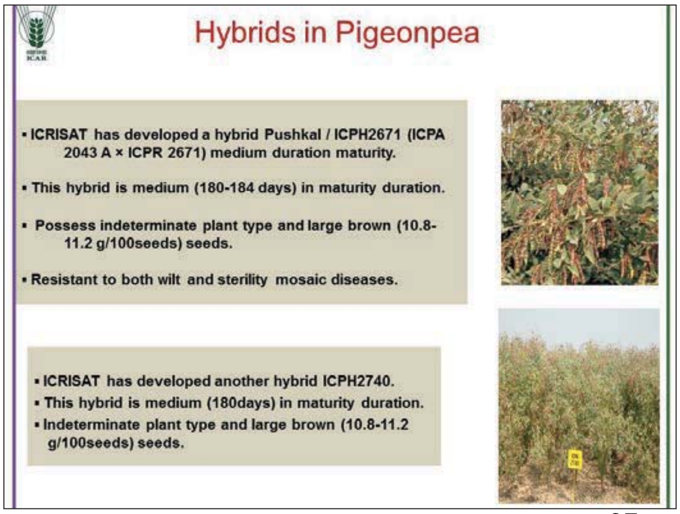
24



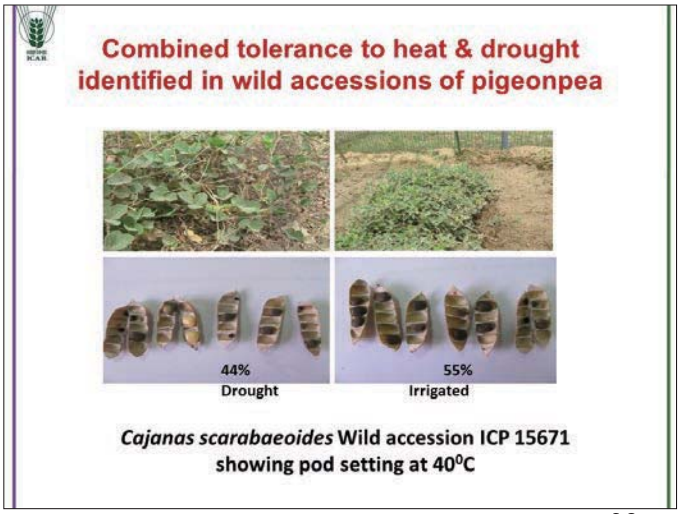

25



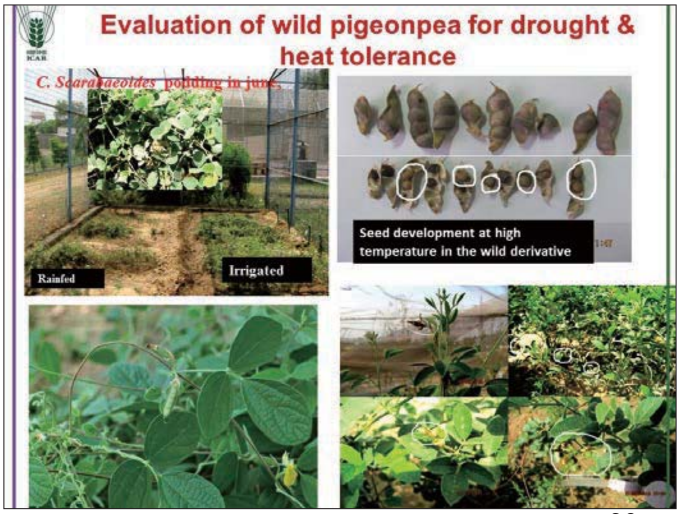

26



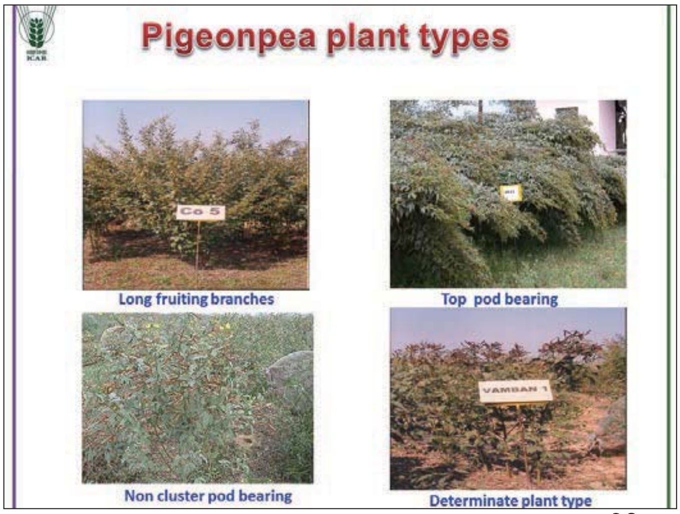

27



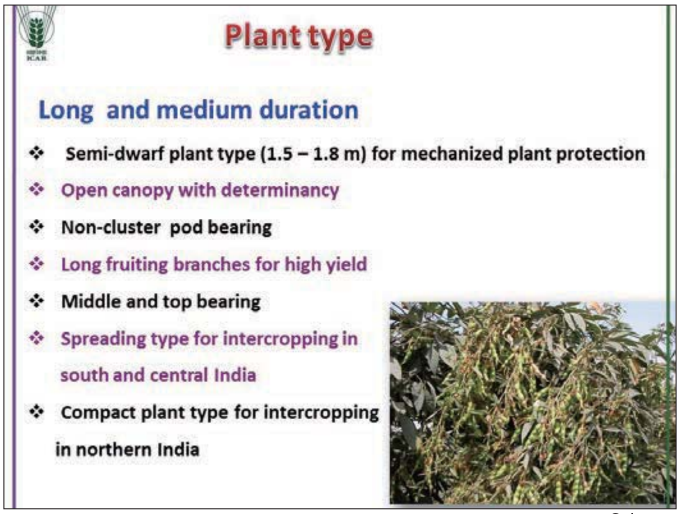

28



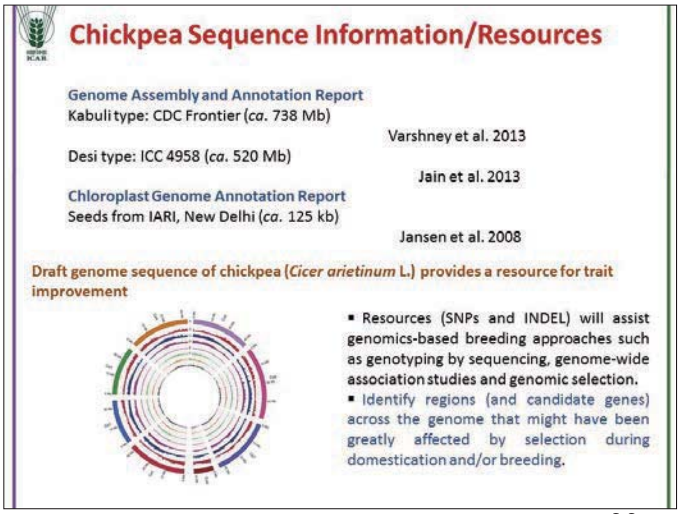

29



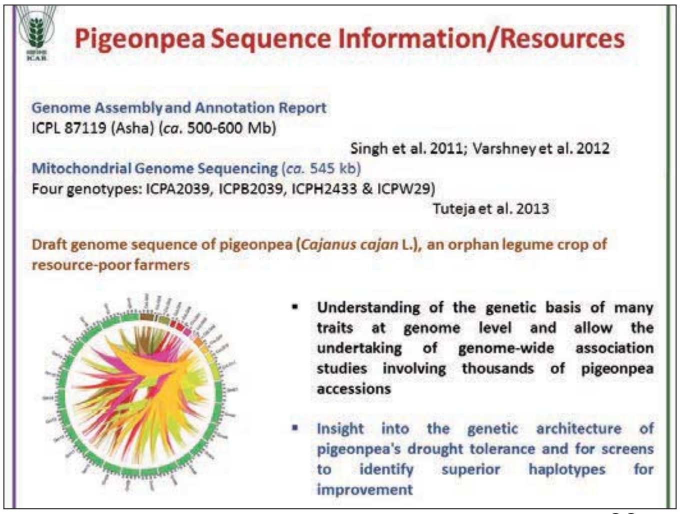

30



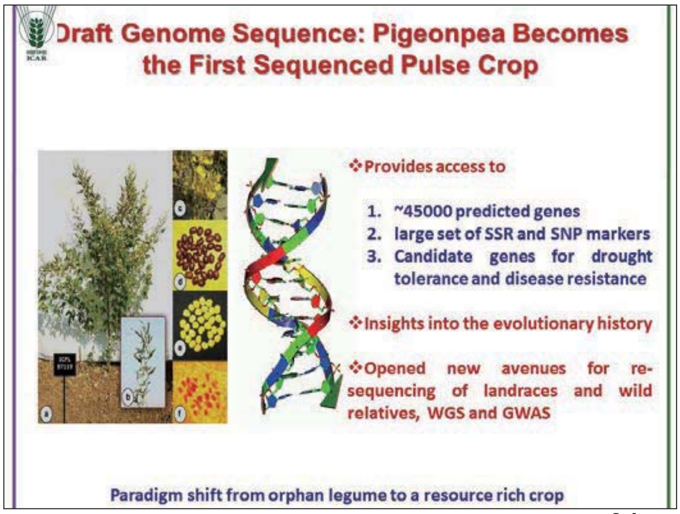

31



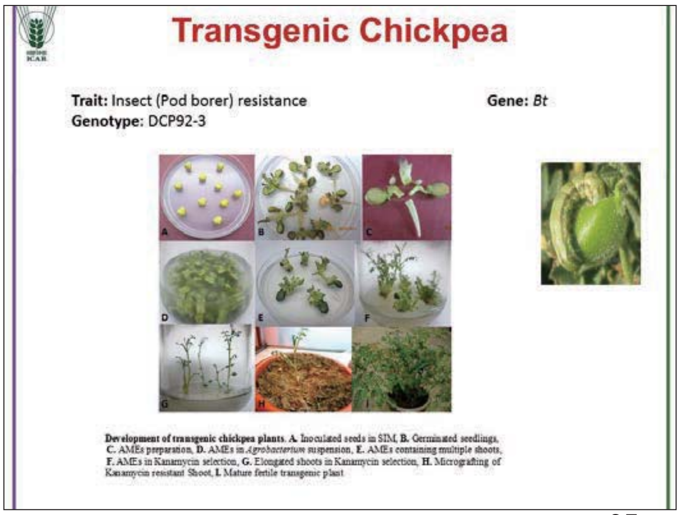

32



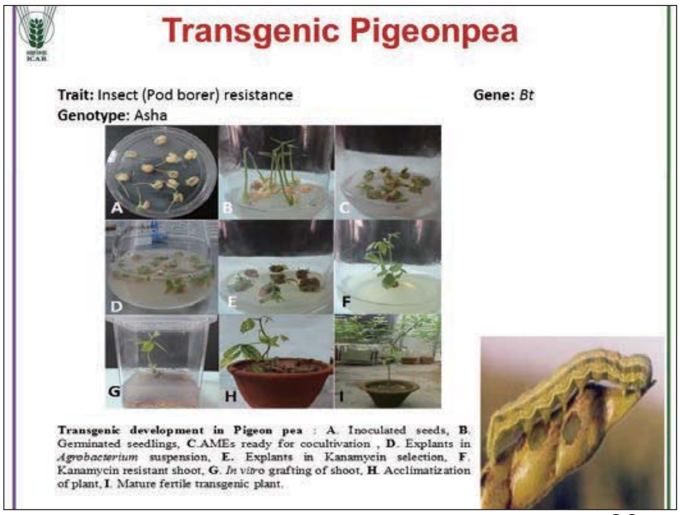

33




34




35

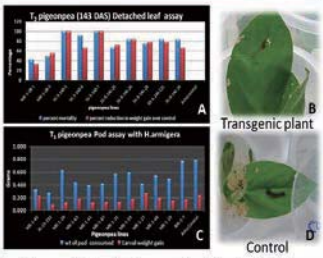



36

## Insect Bioassay of transgenic lines

| Generation | Plants | Mortality |
|---|---|---|
| $T_2$ | 25 | 25-100 % |
| $T_1$ | 12 | 10-60 % |

| Bioassay | Plants | Mortality |
|---|---|---|
| Whole plant | 4 | 20-40 % |
| Detached leaf | 41 | 0-80 % |




Insect bioassay A. Graphical presentation of detached leaf bioassay performed on $T_2$ pigeonpea, B. Leaf of transgenic plants under infestation of *H. armigera* larvae, C. Graph showing results of insect bioassay performed on T1 pigeonpea pods, D. Non transgenic leaf infested by *H. armigera*

Fig. Whole plant bioassay in chickpea
A- Acrylic cage, B- Small iron cage with insect net, C- Large iron cage with insect net

37

## Other Initiatives

Marker Assisted Back Crossing adopted for introgression of drought QTL and resistance to diseases or their physiological races through MARS to desirable backgrounds

Promising Introgression Lines of JG 11 identified

38

## Molecular Breeding

### Development of mapping populations

| Crop | Trait | Mapping populations |
|---|---|---|
| Chickpea | Heat | ICCRIL 12 ICC 4567 × ICC 15614 |
| | Seed protein content | DCP 92-3 x T 39-1 |
| Pigeonpea | Wilt | T 7 x Maruti |
| | Sterility Mosaic Disease | UPAS 120 x Asha |

39

## MABC for introgression of *Fusarium* wilt (race 2) resistance in chickpea (BG 256 x Vijay)

| Markers used in foreground selection and plants selected during different generations | BC3F2 (Set I) | | | BC2F2 (Set II) | | |
|---|---|---|---|---|---|---|
| | Analysed | Scorable bands | Heterozygotes | Analysed | Scorable bands | Heterozygotes |
| TA 110 | 161 | 144 | 67 | 258 | 221 | 64 |
| TA 37 | 161 | 149 | 66 | 258 | 220 | 95 |
| Common heterozygotes for both markers for background selection | | | 46 | | | 39 |
| No. of SSR markers used for background selection | | | 31 | | | 31 |
| No. of plants after background selection (With % recurrent parent genome recovery) | | | 29 (78-89%) | | | 29 (72-84%) |
| Plants selected with higher background genome recovery | | | 16 (90-93.5%) | | | 13 (85-93%) |

40

## MABC for introgression of *Fusarium* wilt (race 2) resistance in chickpea

Disease reaction of parental and BC3F3 and BC3F2 lines carrying foc2 conferring resistance to race 2 of *Fusarium oxysporum*

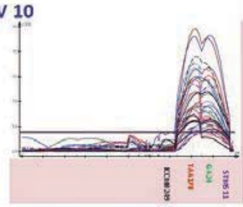
| Lines | FW incidence (%) | Disease Reaction |
|---|---|---|
| Parental lines | | |
| Pusa 256 | 39.5 | moderately susceptible |
| Vijay | 6.7 | Resistance |
| MABC lines | | |
| VD2/145 | 0 | Resistant |
| VC 16/10-2 | 0 | Resistant |
| VD 2/116 | 0 | Resistant |
| VC 35/5-4 | 5.2 | Resistant |
| VC 35/5-8 | 5.7 | Resistant |

41

## Introgression of drought QTLs in elite chickpea cultivars

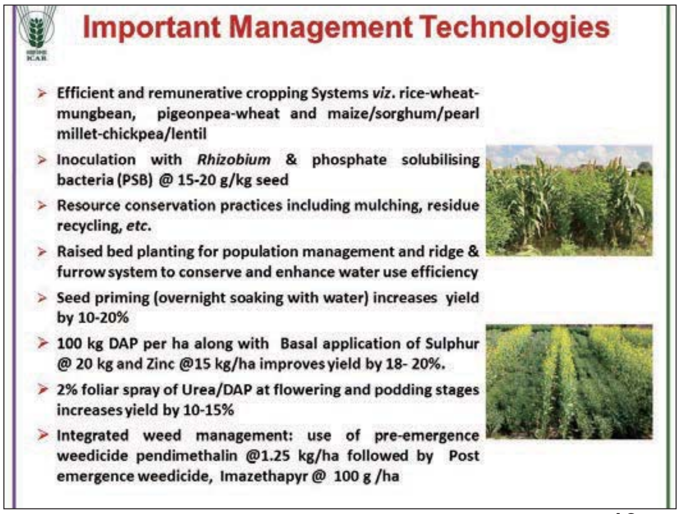
Donor: ICC 4958

Recipients: DCP 92-3, Pusa 362, Pusa 372, ICCV 10

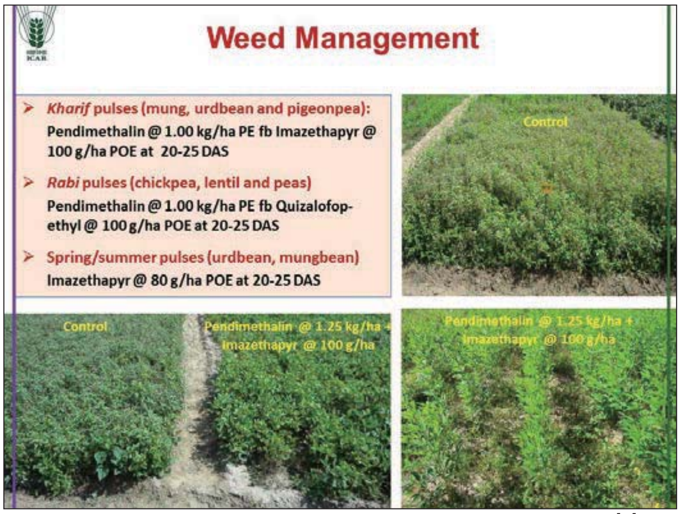



Drought QTL linked region used for foreground selection

42

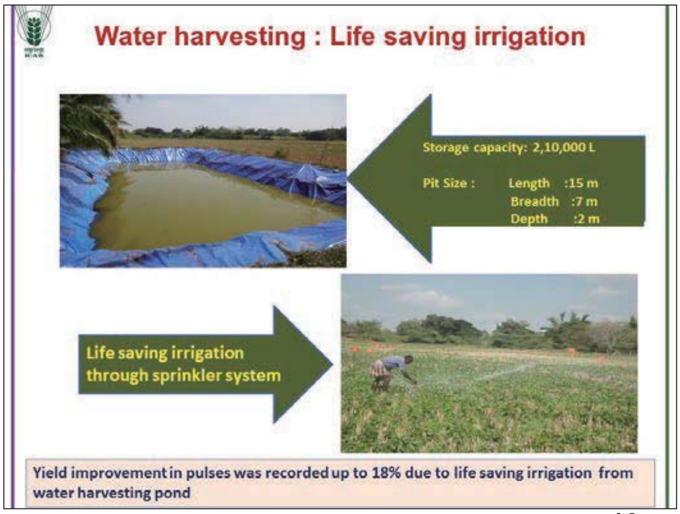



43



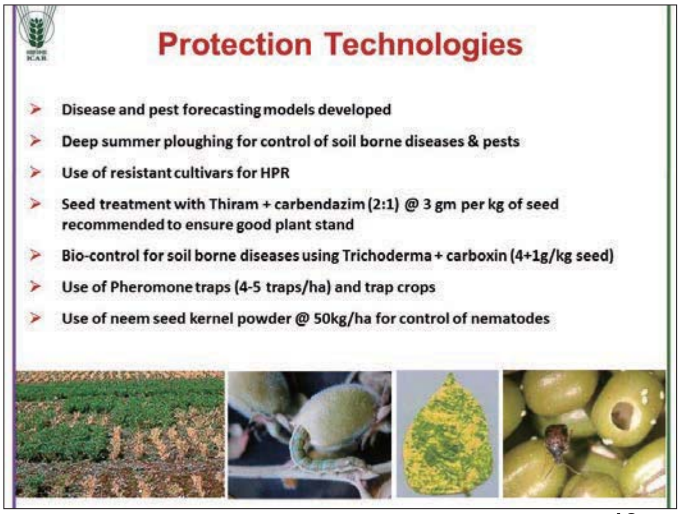

44


45




46


47




48


Scope of Mechanization in Pulse Production
Field preparation - Ridge maker
Sowing- Tractor operated seed drill
Pre-emergence herbicide spray
Weeding through power operated weeders
Spraying – multi bloom sprayer
Harvest – combined harvester

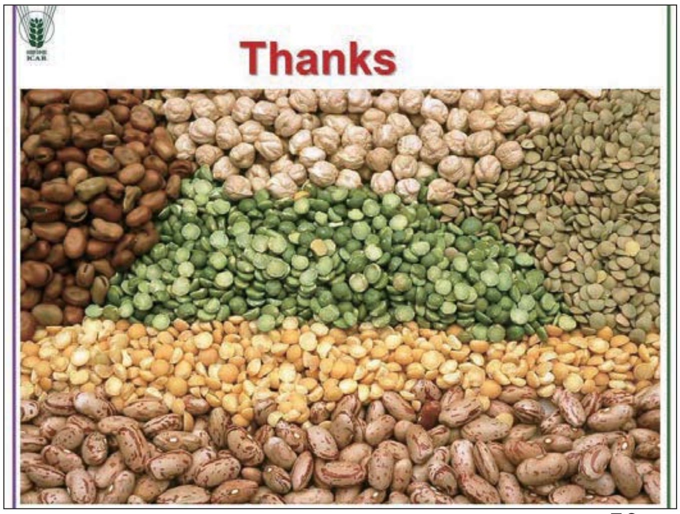
49


Dissemination of Technologies
Farmers' participatory seed production
Farmer to farmer extension model
Front Line Demonstrations
International and national training programmes
Farmers' days, field days, farmers' fair
Farmers' friendly literature
PulsExpert system

50


Way Forward
Development of super early types
Photo-thermo insensitive varieties
Climate resilient varieties
Super nodulating plant types
Multiple disease resistance
Insect smart plants
Hybrid - pigeonpea
Transgenic varieties for biotic and abiotic stresess
Tools
Pre-breeding
Nanotechnology and binformatics
Genomics & molecular marker assisted breeding
Transgenic chickpea and pigeonpea
Nutrient & water management
Input Use Efficiency

51


Thanks

52

**Chair Nakashima**
Welcome to Session 2. My name is Kazuo Nakashima, Program Director of the Stable Agricultural Production Program of JIRCAS. I am the Chairperson for this session titled ‘Legumes all over the world: Use of the diversity for improvement.’ Please allow me to give an introduction about this session.

The legume family includes approximately 650 genera and 18,000 species worldwide. Among edible leguminous plant species, about 80 are economically significant. Researches are carried out over the utilization of genetic resources and further improvement. JIRCAS conducts researches to evaluate and utilize cowpea genetic resources and develop soybeans that are tolerant to adverse environments. These photographs, the left photograph shows various types of cowpea grains and cowpea dishes on the right.

Our research studies at JIRCAS have produced variable results. For instance, we have released the EDITS-Cowpea database of cowpea genetic resources. We have also succeeded in developing soybeans that are tolerant to high salinity conditions in the field. For more information, please view our posters later.

These are three presentations for this session. The first presentation is about the pulses research in India, especially chickpea and pigeonpea. And the second presentation is regarding the *Vigna* research under stress environments. The last presentation is about soybean research for disease resistance.

Similar to the previous session, 15 minutes will be allotted for presentations and 5 minutes for questions. So, before we begin Session 2, let us all switch our mobile phones to silent mode. Thank you for your cooperation.

Let’s start the session. The first speaker is Dr. Girish Prasad Dixit. He is Project Coordinator of chickpea at the Indian Institute of Pulses Research, India. He has developed about 10 high yielding varieties of pulse crops which are very popular in India. The title of his presentation is ‘Importance of pulses research in India: Chickpea and pigeonpea. Dr. Dixit, please go ahead.

**Dr. Girish Prasad Dixit**
Thank you Chairman. My name is Girish Prasad Dixit. I am chickpea coordinator for Indian National Program, and I have been asked by the organizer to speak on the pulses research activities in India with emphasis on pigeonpea and chickpea.

As you all know, pulses constitute an important dietary constitute for human and animals because of their richness in protein and other essential minerals, vitamins, dietary fiber. In India, over a dozen of pulse crops are grown in one or other part of the country. However, the most important pulse crops grown are chickpea and pigeonpea.

Here I have given the list of different pulses being grown there and among these crops, chickpea is number 1. The share to the total pulse production is about 50%. The next crop is pigeonpea, which has a share of about 20% to the total pulse production. So, if you take chickpea and pigeonpea together, roughly 70% of the total pulses comes from these two crops.

Other crops are mung bean, black gram, peas that is the dry pea, lentils, Phaseolus or kidney bean, Lathyrus, and there are other crops like cowpea, guar. Although they are not much popular as a pulse crop, but they are still being grouped under the pulse category.

Now, coming to the very important point, why pulses are so much important in India? As I mentioned that it is needed for the nutrition security because if you see the food habit of the Indians, they are mostly vegetarian and they are largely dependent for their protein requirement from pulses and the content of protein in the pulses is more than 20%. So, it is very much required for the nutritional security of the Indian population. Apart from the human health, it is equally important for the soil health. And there has been an estimate that about 1.5 million ton of nitrogen is annually fixed by the pulses and out of this, a very small quantity is being used by the pulses and rest is left in the soil and therefore they are very important for the sustainable production system. If you see in

India, there is a lot of pressure on the soil because of rice-wheat system, and because of that, the total factor productivity is going down, and therefore, policymakers are thinking very seriously to introduce pulses in between rice-wheat system so that you can diversify the system and make the system more sustainable.

Here I have tried to give the status of pulses in Asia. India is the major producer as well as consumer of the pulses and if you see the share, I think more than 50% production comes from India. Then, other important countries are China and Myanmar. Of course, Japan is not mentioned here because here you are growing peanuts and soybean and that is not included as pulses.

If you see the pulses scenario in India, there has been a stagnation in the acreage but production has increased by 5% in the last 6-7 years, but our requirement is much more and if you see the last 2 years, the weather was not very much favorable, and because of that, the production came down and the import was increased. In India, if you see the share of different pulses, 50% is chickpea, then there are other crops, the share is less than that. So, chickpea is very important as far as India is concerned.

Now, the issues which affect the pulse production. As mentioned by Dr. David in the morning that it is mostly grown as a rainfed crop in India, so the productivity varies over years, and because of that, the profitability is low if you compare with the cereals. And because of this wide fluctuation over years, the price realization is also very poor. So, wherever there is no irrigation, farmers have no other option, they go for the pulses. Most of the areas in the south and central India is like that only that is drought-prone and therefore farmers have no other option but to depend on pulses only.

Pulses are more vulnerable to disease and pest because they are protein rich. If it is protein rich, they are more attracted by the insect and pest also. So, keeping these things in mind, these are our focus areas. I have categorized under two groups, one is to improve the yield potential by different means like prebreeding, then we are trying to modify the plant types, and also we are in search of nutrient and water efficient types. Then, for maximizing the realization of the yield potential through different management practices, we have worked out the economy of different components. We are trying to reduce the yield losses through biotic and abiotic stresses through host plant resistance, to management practices. Also, another area to reduce the cost of production and to make it more economical, viable, mechanization and herbicides are equally important for pulses also. So, this is another priority area.

Here I have briefly given the achievements of these two crops i.e. what we have achieved in the last few decades. In chickpea, we have successfully reduced the duration by 25 days, and because of this, now the crop has been introduced in the new areas of south and central India where the window is of 100 days or so. Earlier we were not able to grow this crop in south India, but now because of reduction in the duration by 25 days, now this crop is fitting well in that system.

Another very important aspect is kabuli chickpea where we have increased the seed size from 35 gram to 55 gram, now it is called extra-large seeded kabuli and now India is exporting this kabuli chickpea to Middle East and other countries.

In general, pulses are not responsive to inputs. If you apply nitrogen or irrigation, they will not respond. There will be excessive growth resulting in very poor yield. But recently we have developed some chickpea varieties which are responsive to high nitrogen as well as irrigation and have very high level of resistance to wilt which is a very serious problem of all the chickpea growing areas in India.

As the crop is mostly rainfed, it is bound to suffer because of high temperature as well as drought during the reproductive phase. So, keeping these in view, we initiated very strong breeding program. Now, we have very good varieties which are tolerant to heat and also tolerant to drought.

In case of pigeonpea, we have successfully reduced the duration by 100 days. Earlier we had the traditional varieties where duration used to be about 220, 240 days. Now, we have varieties of 140 days. Because of that, now it is fitting well in pigeonpea-wheat system. Hybrids have come out in the last one decade. Several hybrids have been developed based on the cytoplasmic genetic male sterility system. I will be discussing later about this. Then, several machine harvest varieties in the case of chickpea have come.

Here, I have given the list of high yielding varieties pulses, all the crops, but if you see in the chickpea, it’s 89 and pigeonpea 36, so fairly good number of varieties are available in pulses. These are the trait specific varieties. More than 14,000 accessions are there in our gene banks, including landraces and wild species. And this is Wide Hybridization Garden recently been established at our institute at IIPR Kanpur where all the wild species and landraces arebeen maintained and has being shared to our cooperators in the country.
Another very important component is restructuring of plant type in chickpea. You see there is a demand from the farmer that you breed erect type and having podding on the top it can be available for machine harvest. And we have developed such varieties, spreading to erect type, podding on the top and now it can be harvested from the combine. So, a lot of material has been developed. They are in the multi-location evaluation, already we have commercialized some varieties for farmers.

Another very important trait is heat stress in chickpea. For high temperature, we have several cultivated as well as wild accessions which we have identified where the pollen germination and pollen tube growth is normal if the temperature goes beyond 35 degrees centigrade. So, it is a very important trait and now we are trying to transfer this trait in all our cultivated varieties in chickpea.

Herbicide tolerance is another very important component, and we have initiated this study very recently, 2 years back, and on the basis of 2 years screening, we have identified some of the herbicide tolerant chickpea lines. Now, we are going to use them in our regular breeding program.

Phosphorous is very important for the pulses. It is available in the soil, but plant is not able to use it. So, we are searching for genotypes which are having better phosphorous acquisition efficiency, and you can see some variability we have observed on basis of that, we can say that there is variability available for phosphorus use efficiency and now there is scope to use this component in our breeding program.

This is a facility which we have created for our breeders, particularly for chickpea breeders where they we can take two to three crops of chickpea in a single year. So, it is very good for the plant breeders for rapid generation advancement. So, it has increased efficiency of plant breeding program.

Now, the second crop is pigeonpea. Just like chickpea, here I have given the list of varieties for different traits. You can see, they are very popular and being adopted by the farmers. And very important aspect in the chickpea is to develop hybrids and in the last two decades a lot of efforts were made. Earlier, we had a genetic male sterility system, but it failed and because of that, now we have to work on the cytoplasmic genetic male sterility system and that has worked very well in pigeonpea. Now, we have standardized the restoration process. This was the first line which we evolved through the cross of Cajanas that is cultivated with this wild species, scarabaeoides and GT288 A was developed and this revolutionized the hybrid pigeonpea program in the country, and by using that line, we could see the first hybrid as GTH1 evolved in 2007 and after that a number of hybrids have evolved. Then, these are some of the hybrids developed by ICRISAT. They are very popular in central and south India.

Just like chickpea, in pigeonpea also, we are in search of lines which have combined tolerance to heat and drought because again it is a rainfed crop grown in a very hardy situation and we have identified certain accessions where the podding is normal even if temperature goes beyond 40 degrees centigrade temperature. Here, you can see some of the wild species. Scarabaeoides is a wild species of pigeonpea where we have screened and now it is being used in developing different plant types.
In the morning, David mentioned about the genome sequencing in chickpea as well as pigeonpea. Now a lot of genomic information is available both in cases of chickpea as well as pigeonpea. We have moved towards the utilization part that is how to use it in the molecular breeding program. We have identified large number of markers and now trying to integrate with our gene of interest to make this breeding procedure more efficient.

Another area is transgenic, pod borers is a major threat in the case of both chickpea as well as pigeonpea and we don't have any resistance source in cultivated as well as wild species. Therefore, transgenic is the only option and both in case of chickpea as well as pigeonpea at our institute at Kanpur, we have developed transgenic. It is in advanced stage of testing. Now, we are waiting for the signal from Government of India. Once it is given, we can go for the testing of this transgenic in multi-location trials so that it can be used in the breeding program for transferring this trait in the adapted varieties of different zones.

Another area is the molecular breeding where we have evolved several lines where the introgression of drought QTL as well as resistance genes in the cultivated types. You can see here the various mapping population being developed for different traits, how this introgression is going on. Then, for drought also how in the cultivated types we are transferring this drought tolerance from the donors to the adapted varieties. These are some of the management technologies being recommended by our agronomist and physiologist. Weed is a serious issue in the case of pulses and several management practices have been worked out. Chickpea is grown mostly in the drought situation and therefore moisture stress is a serious problem. We don't have irrigation in those areas. So, on the conserved moisture, it is being grown and farmers are being suggested to follow a drip system where you can economize the use of water, and this kind of water harvesting is being now encouraged. You conserve this water and try to give just one lifesaving irrigation by drip. It is going to enhance yield by 18 to 20%.

For the processing / milling at the farmers' level, some small milling structures are now being developed and now it is being popularized among the farmers.

Protection technologies have been standardized, whether it is biocontrol, seed treatment, biopesticides. Mechanization has a lot of scope and there is continuous demand from the farmers and our engineers have successfully developed different implements and now they are being popularized among the pulses farmers.

For dissemination of our technologies, Farmers' participatory seed production is very important component, we are developing varieties, then farmer to farmer extension model and there are other extension activities being followed.

Photo-thermo insensitivity is very important trait. In the case of mung bean and other crops it has been achieved but not in the case of chickpea and pigeonpea, so it is going to be a challenge. So, with this, I come to the end and before I close, I would like to thank the organizers for giving me opportunity to share my views about Indian Pulses Program. Thank you.

**Chair Nakashima**
Thank you for the informative presentation, Dr. Dixit. We were able to know the current situation about the research on the pulses in India, especially pigeonpea and chickpea. So, the floor is now open for discussion. Are there any questions or comments? No questions or comments? Okay.

**Male Questioner**
Thank you very much. I think it's great. You have achieved much progress in heat and drought tolerance in pulses. I want to know if there is any trade off between stress tolerance and quality of grain, sometimes we observe if some crop get to stress tolerant, it deteriorates the quality of grain. So, I want to know stress tolerant pulses variety, its quality is enough for farmers to be adapted or not.

**Dr. Girish Prasad Dixit**
Actually, some of the wild species have this trait, but there is some problem with respect to crossability with our cultivated types, but it is underway and very soon we will be able to transfer that trait. Once it is transferred, then the storage pests like bruchid and other insects can be managed by that.

**Chair Nakashima**
Okay. Next.

**Male Questioner**
One question that is also related with his question. When you develop some breeding lines, for example the good type to harvest, narrow line from wider line, or in some case the resistant line, his question and my question also may be same, is there any demerits or tradeoff some of the good quality when you developed your new varieties that was off, high yield was decreased?

**Dr. Girish Prasad Dixit**
Because of restructuring the plant types, it is not going to be affected. Once it is affected, we are not going to release it as a variety. If it is to be released as a variety, it should be more productive than what is being grown by the farmer. So, that criterion is always kept in mind, whether it is yield or any quality traits.

**Male Questioner**
Okay. In the case of the resistance to drought or something, is there some of the good character lost when you developed?

**Dr. Girish Prasad Dixit**
Through regular breeding, there is chance, but if you are going through molecular breeding, you are targeting a very specific trait. So, there is no scope of deviation from the quality.

**Chair Nakashima**
Okay. I'm afraid the time is up. So, thank you again, Dr. Dixit.