PL-7: Herbicide-tolerant, machine-harvestable chickpea, faba bean and lentil varieties

Pooran Gaur
Principal Scientist (Chickpea Breeding) & Theme Leader, Crop Improvement
ICRISAT, Patancheru 502 324, Telangana, India
p.gaur@cigar.org

5 October 2016

http://grainlegumes.cgiar.org

Leveraging legumes to combat poverty, hunger, malnutrition and environmental degradation
Product Line Description

- Harvesting and weeding in grain legumes are largely done manually in the developing countries.
- These field operations are becoming increasingly expensive because of the rising labor cost and shortage of labor at the peak time of requirement.
- These field operations are largely carried out by women and cause drudgery on them.
Product Line Description  Cont...

- Delay in crop harvests leads to significant losses of grains and their quality.
- Weed management by herbicides can help expanding conservation agriculture.
- Herbicide tolerant and machine harvestable varieties will increase mechanization, reduce cost of cultivation, reduce drudgery on farm women and make legume cultivation more attractive and profitable to farmers.
Proposed outputs

Five-year outputs

- Sources for tolerance to herbicides and parasitic weeds and traits required for amenability of crop to mechanical harvesting identified, and breeding lines developed
- Cultivars suitable to mechanical harvesting developed and evaluated on farmers’ fields

Ten-year outputs

- Improved cultivars with herbicide tolerance and machine harvestability developed and evaluated
- At least 10% of crop area in target regions brought under the improved varieties amenable to mechanical harvesting
RESULTS
Analyzing demand and setting research priorities (FP 6)

- A survey conducted in Karnataka state revealed that the labor cost accounted for about 32% of the total variable cost incurred in chickpea cultivation.

- A survey conducted in Maharashtra and Madhya Pradesh states of India found that the profit from machine harvesting over manual harvesting and machine threshing was in the range of USD 42 to 49 per ha.

- The farmers want machine harvestable and herbicide tolerant chickpea varieties due to scarcity of labors and increasing labor wages.
Development of machine harvestable varieties in chickpea, lentil and faba bean (FP 3)

- Breeding efforts accelerated.
- Existing tall and erect/semi-erect lines extensively evaluated and new breeding materials rapidly generated.
- Large number of machine harvestable, high yielding breeding lines identified/developed in all 3 legumes.
- A network project on “Machine harvestable and Herbicide Tolerant Chickpea” supported by NFSM and involving 7 research institutes was started in India.
- A separate trial on machine harvestable breeding line started under All India Coordinated Research Project (AICRP) on Chickpea.
Demonstrations on machine harvestable varieties at farmers’ fields (FP 4 & 6)

Demonstrations on machine harvestable chickpea breeding line NBeG 47 on farmers’ fields in Andhra Pradesh, India

<table>
<thead>
<tr>
<th>Year</th>
<th>No. of demos</th>
<th>JG 11 (Yield kg/ha)</th>
<th>NBeG 47 (Yield kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013-14</td>
<td>21</td>
<td>1616</td>
<td>1731</td>
</tr>
<tr>
<td>2014-15</td>
<td>12</td>
<td>1575</td>
<td>1608</td>
</tr>
<tr>
<td>2015-16</td>
<td>16</td>
<td>1450</td>
<td>1454</td>
</tr>
</tbody>
</table>

- NBeG 47 gave yield similar to or higher than JG 11 and was amenable to machine harvesting.
- NBeG 47 has been released in Andhra Pradesh in 2015.
Field days organized to demonstrate machine harvesting of new varieties to farmers and extension personnel (FP 6)

A Field Day organized to demonstrate machine harvesting of chickpea variety GBM 2 in Karnataka, India
## Development of Machine Harvestable Varieties (FP 3)

<table>
<thead>
<tr>
<th>Crop</th>
<th>Country</th>
<th>Variety</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chickpea (12)</td>
<td>Turkey</td>
<td>Seckin, Arda, Hasanbey</td>
</tr>
<tr>
<td></td>
<td>Lebanon</td>
<td>GHAB5</td>
</tr>
<tr>
<td></td>
<td>Tunisia</td>
<td>Nour</td>
</tr>
<tr>
<td></td>
<td>Georgia</td>
<td>Aragui</td>
</tr>
<tr>
<td></td>
<td>Azerbaijan</td>
<td>Garaja</td>
</tr>
<tr>
<td></td>
<td>Iran</td>
<td>Saral</td>
</tr>
<tr>
<td></td>
<td>Kazakhstan</td>
<td>Vostok</td>
</tr>
<tr>
<td></td>
<td>Russia</td>
<td>Baraev</td>
</tr>
<tr>
<td></td>
<td>India</td>
<td>NBeG 47, GBM 2</td>
</tr>
<tr>
<td>Lentil (5)</td>
<td>Turkey</td>
<td>Bozok, Gumrah, Karagul, Tigris</td>
</tr>
<tr>
<td></td>
<td>Syria</td>
<td>Idlib 5</td>
</tr>
<tr>
<td>Faba bean (4)</td>
<td>Syria</td>
<td>Hama 2, Hama 3</td>
</tr>
<tr>
<td></td>
<td>Ethiopia</td>
<td>Didea</td>
</tr>
<tr>
<td></td>
<td>Mexico</td>
<td>Santa Elena</td>
</tr>
</tbody>
</table>

### Seed production (FP 4)

- About 1778 tons of basic/breeder seed produced with NARS
- About 5442 tons certified/QDS seed produced with farmer seed producer groups
First machine harvestable chickpea variety boon for Andhra Pradesh farmers: bit.ly/1QprW7p
@ICRISAT

Scientists develop chickpea harvestable by machine
Mobile Crushing Machine - Shanghai Mobile Crushing Machine. Order 90-650TPH Primary jaw crusher
shanghai-crusher.com/mobile_crusher

First machine harvestable chickpea variety released in AP
February 4, 2016 | UPDATED 19:45 IST

Pulses: New machine-harvestable chickpea plant developed
Determining optimum plant density for machine harvestable varieties (FP 1)

- It is expected that the machine harvestable varieties (tall and upright growth) may require higher plant density than the currently grown semi-spreading varieties.

- Two tall chickpea lines (GBM 2 and NBeG 47 in Central and Southern India; GNG 1581 and HC 5 or PUSA 1103 in Northern India) were evaluated in four different planting densities (30 cm x 10 cm; 30 cm x 7.5 cm; 22.5 cm x 10 cm; 22.5 cm x 7.5 cm).

- The trial was conducted at two locations in southern India (Nandyal, Dharwad), one location in central India (Sehore) and three locations in Northern India (Ludhiana, New Delhi, Kanpur).

- Closer row and/or plant spacing of 30 cm x 7.5 cm and 22.5 cm x 10 cm gave higher yield than the normal spacing (30 cm x 10 cm) at most locations.
Herbicide tolerance in chickpea (FP 2)

- A large number of chickpea genotypes were screened for tolerance to Metribuzin (575), Imazethapyr (1251) and Carfentrazone-ethyl (376).
- Sources of tolerance identified for each of these herbicides.
- In general, the sensitivity of the genotypes to Metribuzin was higher compared to other herbicide.
- Herbicide sprayed crop showed 8 to 15 days delayed maturity as unsprayed control.
Herbicide tolerance in lentil (FP 2)

- Over 700 germplasm lines screened for tolerance to Imazethapyr and Metribuzin
- Delay in flowering, poor pod setting and reduction in plant height observed in herbicide treated plot.
- Germplasm lines tolerant to both herbicides identified

<table>
<thead>
<tr>
<th>Herbicide</th>
<th>Genotype</th>
<th>Tolerance score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metribuzin</td>
<td>ILL6434</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>ILL89517</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>ILL10810</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>ILL10833</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>ILX87075</td>
<td>2</td>
</tr>
<tr>
<td>Imazethapyr</td>
<td>ILL8009</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>ILL5988</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>ILL4994</td>
<td>2</td>
</tr>
</tbody>
</table>
In reference set of faba bean, 25 genotypes were tolerant to Metribuzin and 24 tolerant to Imazethapyr.

4 genotypes (IG 99328, Spanish 845, Spanish 972 and INRA 2583) did not have any damage while applying a combination of Metribuzin and Imazethapyr.

Number of genotypes

<table>
<thead>
<tr>
<th>Metribuzin treatment</th>
<th>Imizathapyr treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

Number of genotypes (2-5)
Development of herbicide-tolerant transgenic chickpea (FP 2)

- Several herbicide tolerant transgenic crops (e.g. soybean, cotton, maize) are under cultivation. In 2015, these were grown globally in 95.9 m ha (53% of the total area of GM crops).

- Transgenic chickpea events were developed by introducing soybean cytochrome cDNA CYP71A10 that encodes a P450 enzyme capable of metabolizing phenylurea herbicides.

- At least 6 T1 transgenic events showed high resistance to pre-emergence application of herbicides Linuron and Chloroturon, which are photosynthesis inhibitors.

- Evaluation of these events for post emergence tolerance to metribuzin is currently underway.
Mutation breeding for herbicide tolerance (FP 2)

- A mutation breeding program for herbicide tolerance in chickpea was undertaken at 7 research institutes in India in the network project funded by NFSM.

- EMS was used for mutagenesis of 14 cultivars, including JG 11, JAKI 9218, JG 16 and KAK 2.

- M2/M3 populations of some cultivars were screened and putative herbicide tolerant mutants were harvested. Progenies to be screened.

- TILLING population (M3) of ICC 4958 was screened for tolerance to herbicide Imazethapyr but none of the lines was found tolerant.

- Mutation breeding for herbicide tolerance initiated in lentil.

- Two EMS-induced mutant lines (Mu-38 and Mu-418) of faba bean variety BPL 310 were found tolerant to herbicide glyphosate.
Molecular mapping of QTLS/genes controlling herbicide tolerance (FP 2)

- Remarkable progress has been made in development of genomic resources for grain legumes in the past decade.
- Draft genome sequence of chickpea and lentil are available.
- 40 genotypes representing variability for tolerance to herbicides Metribuzin and Imazethapyr were subjected to whole genome re-sequencing (WGRS) for identifying molecular markers linked to candidate genes.
- RIL mapping populations developed in chickpea for molecular mapping of genes/QTLs controlling resistance to herbicides imazethapyr (ICC 1710 x ICC 14077) and metribuzin (ICC 1205 x ICC 14077) are being genotyped and phenotyped.
- A RIL mapping population of faba bean was phenotyped for Orobanche tolerance in Morocco.

(Varshney et al 2013)
Orobanche resistance in lentil and Faba bean (FP 2)

• Parasitic weeds (*Orobanche* spp.) are also constraints to lentil and faba bean production in many countries (e.g. Ethiopia, Morocco, Tunisia, Egypt).

• A large number of genotypes of lentil (516) and faba bean (1924) were screened for *Orobanche* resistance and genotypes with high level of resistance to *Orobanche* were identified.

• Studies are in progress to identify molecular markers for quantitative trait loci (QTLs) controlling resistance to *Orobanche* in faba bean.
Impacts of Orobanche resistant Faba bean varieties in Egypt (FP 6)

- A survey indicated that 46% farmers were using new varieties and parts of the technology package and 14% were using the full package.
- Recommended technology package increased farmers’ grain yield by 256 kg/ha.
- Reduced production costs by USD 350/ha.
- Increased net income by USD 550/ha.

<table>
<thead>
<tr>
<th>Varieties</th>
<th>Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>Giza 843, Misr 3</td>
<td>Egypt</td>
</tr>
<tr>
<td>Najah</td>
<td>Tunisia</td>
</tr>
<tr>
<td>Hachenghe (ILB 4358)</td>
<td>Ethiopia</td>
</tr>
</tbody>
</table>
Capacity Building (FP 5)

- Ph D students (4 M + 5 F)
- MSc students (4 M + 3 F)
- 16 Training courses (731 M + 117 F)
- 4 Workshops (52 M + 7 F)
- 1 Exposure visit of farmers (20 M + 1 F)
- 9 Field Days (543 M + 132 F)
Lessons Learned

- It is possible to develop machine harvestable varieties with yield levels similar to or higher than the existing high yielding cultivars.

- Increasing labor wages, scarcity of labors in agriculture, and availability of combine harvesters on hiring at the local level and at reasonable rates are encouraging even smallholder farmers to opt for machine harvesting.

- Farmers are already using herbicides for weed control in soybean and keen to use in other grain legumes.

- Though wide variations exist for herbicide tolerance in chickpea, lentil and faba bean, even the most tolerant genotypes show delay in maturity, reduction in plant height and some yield penalty on spray of herbicides.
Areas suggested for continued R4D

- Enhance adoption of recently released machine harvestable varieties by dissemination of information to farmers and ensuring seed availability.

- Further improve machine harvestable varieties for resistance/tolerance to biotic and abiotic stresses, nutritional and grain quality traits, and adaptation to different geographies and cropping systems.

- Continue efforts on development of transgenics, mutagenesis and screening of the germplasm of cultivated and wild species for inducing/identifying enhanced levels of herbicide tolerance.

- Identify candidate genes and diagnostic markers for herbicide tolerance for use in breeding programs.
Contributing Bilateral Projects

- NFSM, Government of India
- Tropical Legumes II & III
- OCP-Morocco, India Project for food legumes
- EU-IFAD project on Grain Legumes
- GRDC-Chickpea Project
- Egypt-ARC-ICARDA collaborative project on faba bean for Orobanche and disease resistance.
Summary

- Cultivars suitable to machine harvesting developed and evaluated on farmers’ fields. Many breeding lines are at different stages of evaluations.
- Sources for tolerance to herbicides and parasitic weeds identified from naturally occurring genetic variability in the germplasm and being used in breeding programs.
- Transgenic technology and mutation breeding are being used for obtaining novel sources and higher levels of herbicide tolerance.
- Faba bean varieties with Orobanche resistance developed.
- Studies are in progress to identify molecular markers for QTLs/genes controlling herbicide tolerance Orobanche resistance.
List of Posters

- Developing chickpea cultivars suitable to machine harvesting (GL 20)
  **Sushil K Chaturvedi**, Pooran Gaur, S Srinivasan, Shailesh Tripathi, Sarvjeet Singh, V Jayalakshmi, AG Vijaykumar, Md Yashin, Neelu Mishra and NP Singh

- Herbicide tolerance in chickpea, lentil and faba bean (GL 21)
  **Sarvjeet Singh**, Pooran Gaur, Fouad Maalouf, SK Chaturvedi, Somanagouda Patil and Shiv Kumar

- Orobanche resistance in faba bean and lentil (GL 22)
  **Fouad Maalouf**, Somanagouda Patil, Karthika Rajendran and Shiv Kumar
Partners

- ICRISAT - India, Ethiopia and Kenya
- ICARDA - Morocco, Lebnon, Egypt and Ethiopia
- Agriculture Research Center, Egypt
- ANGAU Regional Agril. Res. Station, Nandyal, AP, India
- Central Research Institute for Field Crops, Ankara, Turkey
- Ethiopian Agriculture Research Institute, Ethiopia
- General Commission for Agricultural Research, Damascus, Syria
- ICAR-Indian Agricultural Research Institute (IARI), New Delhi, India
- ICAR-Indian Institute of Pulses Research (IIPR), Kanpur, India
- Indian Council of Agricultural Research (ICAR), New Delhi, India
- Institut National de la Recherche Agronomique (INRA), Rabat, Morocco
- Mahatma Phule Krishi Vidyapeeth (MPKV), Rahuri, India
- National Institute of Agricultural Research, Tunisia
- Punjab Agricultural University (PAU), Ludhiana, Punjab, India
- RVSKVV - RAK College of Agriculture, Sehore, MP, India
- University of Agricultural Sciences (UAS), Dharwad, Karnataka, India
- University of Agricultural Sciences (UAS), Raichur, Karnataka, India
Special thanks for support in coordination

Fouad Maalouf and Shiv Kumar, ICARDA

Thank you for your kind attention

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and public and private institutes and organizations, governments, and farmers worldwide

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