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UNITED KINGDOM · CHINA · MALAYSIA

Genetic improvement of winged bean (*Psophocarpus tetragonolobus*) for increased productivity and nutritional security

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Introduction: winged bean

Winged bean-perennial vine grows in hot, humid equatorial countries.

Mostly grown in Papua New Guinea, Indonesia, Malaysia, Thailand and Sri Lanka

Studies from Africa:
-Selection of drought tolerant varieties (Karikari, 1977)
-Comparison on nutritional contents of winged bean with other legumes (Mnembuka & Eggum, 1995)

Winged bean and its benefits

- Multipurpose—grown for pulse, vegetable and tuber.
- Young pods are the most popular edible part.
- Mature seeds are most nutritious—
  - Comparable protein content to soybean (Mnembuka & Eggum, 1995).
  - Oil content comparable to soybean and fatty acid composition comparable to peanut oil (Khor *et al*., 1981)
- Nitrogen fixation efficiency comparable to ureide-transporting legumes such as *Desmodium*, *Siratro* and soybean (Yoneyama *et al*., 1986).

Problems of growing winged bean

- Indeterminate growth habit.
- Home consumption and income generation.
- Need to develop new improved varieties - high yielding and determinate growth habit.

“Increase harvest index”

Specific objectives

- To evaluate morpho-physiological traits of 24 contrasting winged bean accessions.
- To identify simple sequence repeats (SSR) from transcriptome dataset for use in genetic diversity studies.
- To conduct comparative genomics study based on massive parallel transcriptome with model legumes.
- To evaluate differential genotypic expression profile during reproductive development using microarray technology.

List of plant materials

Accession	Country of origin	Climate
M2	Malaysia	Tropical
M3	Malaysia	Tropical
M4	Malaysia	Tropical
M6	Malaysia	Tropical
M7	Malaysia	Tropical
M8	Malaysia	Tropical
T5	Nigeria	Tropical
T9	Dr. T.N.Kahn (1973)	-
T10	Papua New Guinea	Tropical
T12	Liberia	Tropical
T14	Indonesia	Tropical
T15	Indonesia	Tropical
T16	Indonesia	Tropical
T17	Indonesia	Tropical
T18	Dr. D Nangju (1976)	-
T19	Nigeria	Tropical
T22	Papua New Guinea	Tropical
T26	Nigeria	Tropical
T31	Indonesia	Tropical
T33	Unknown	-
T51	Bangladesh	Tropical
T53	Bangladesh	Tropical
319	Sri lanka	Tropical (coastal region)
271	Sri lanka	Tropical (coastal region)

Morpho-physiological characterization

- Location: Semenyih Malaysia (Temp: 27ºC and RH: 80%)
- Duration: 20 weeks

Week 4

Morpho-physiological characterization

Week 8

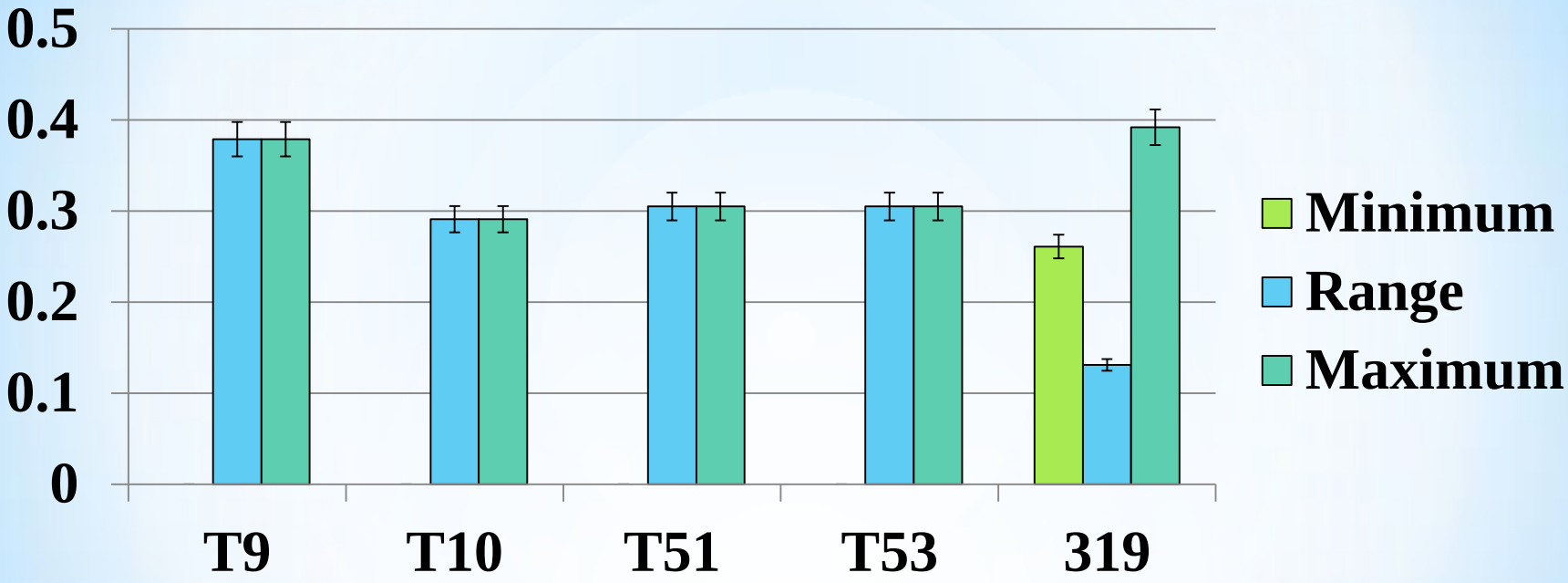
Week 4

Morpho-physiological characterization

Week 8

Week 15

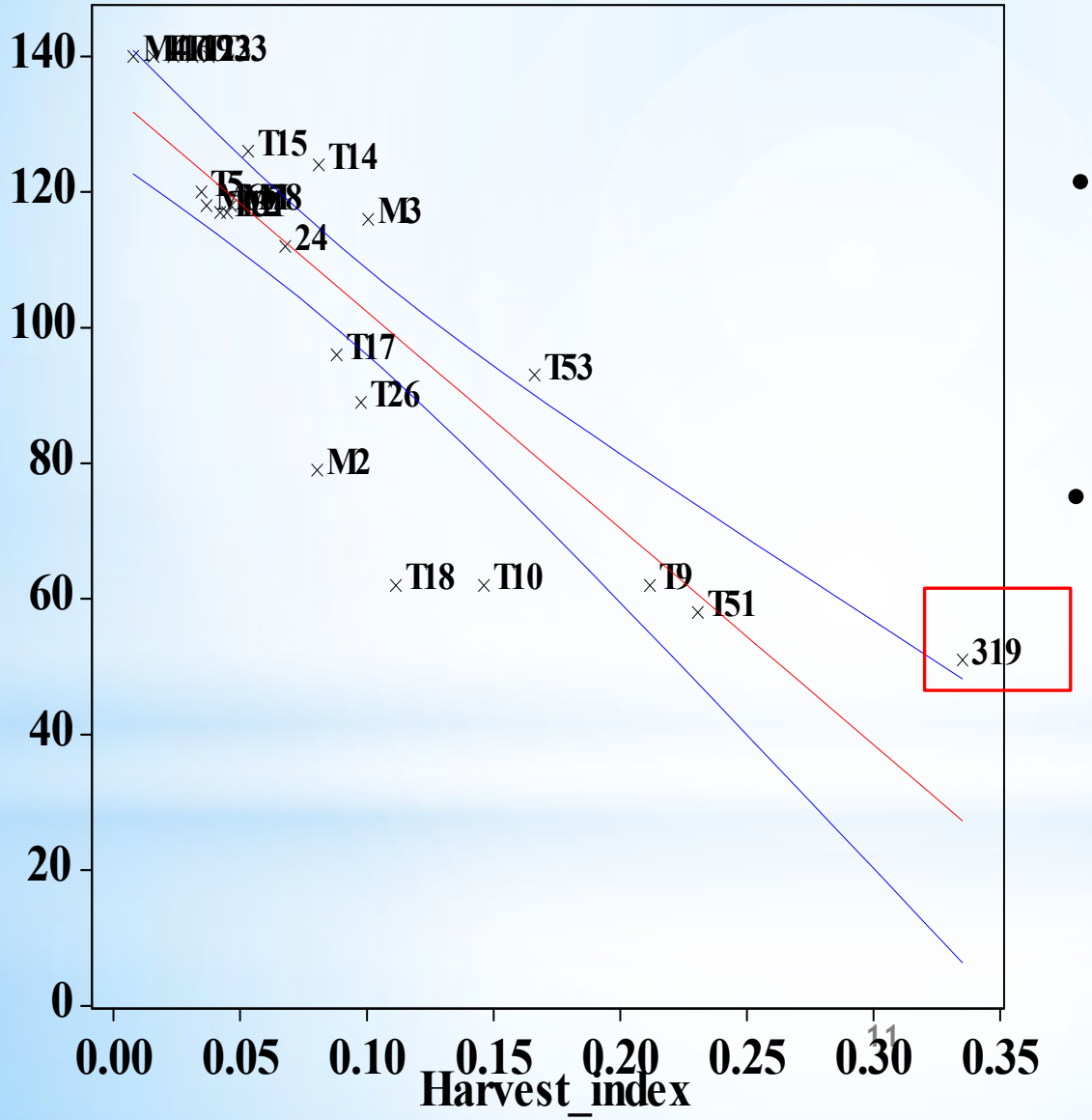
Harvest index



- Across the germplasm, accession 319 has the highest harvest index followed by T51, T53, T9 and T10.
- Significant variations between (F pr.<0.05) and within (t<0.05) the accessions would suggest that yield improvement is possible through selection of accession and better material within accession.
- Based on the range values, individual plants within 319 showed better consistency in yielding.

What if we relate harvest index to flowering time?

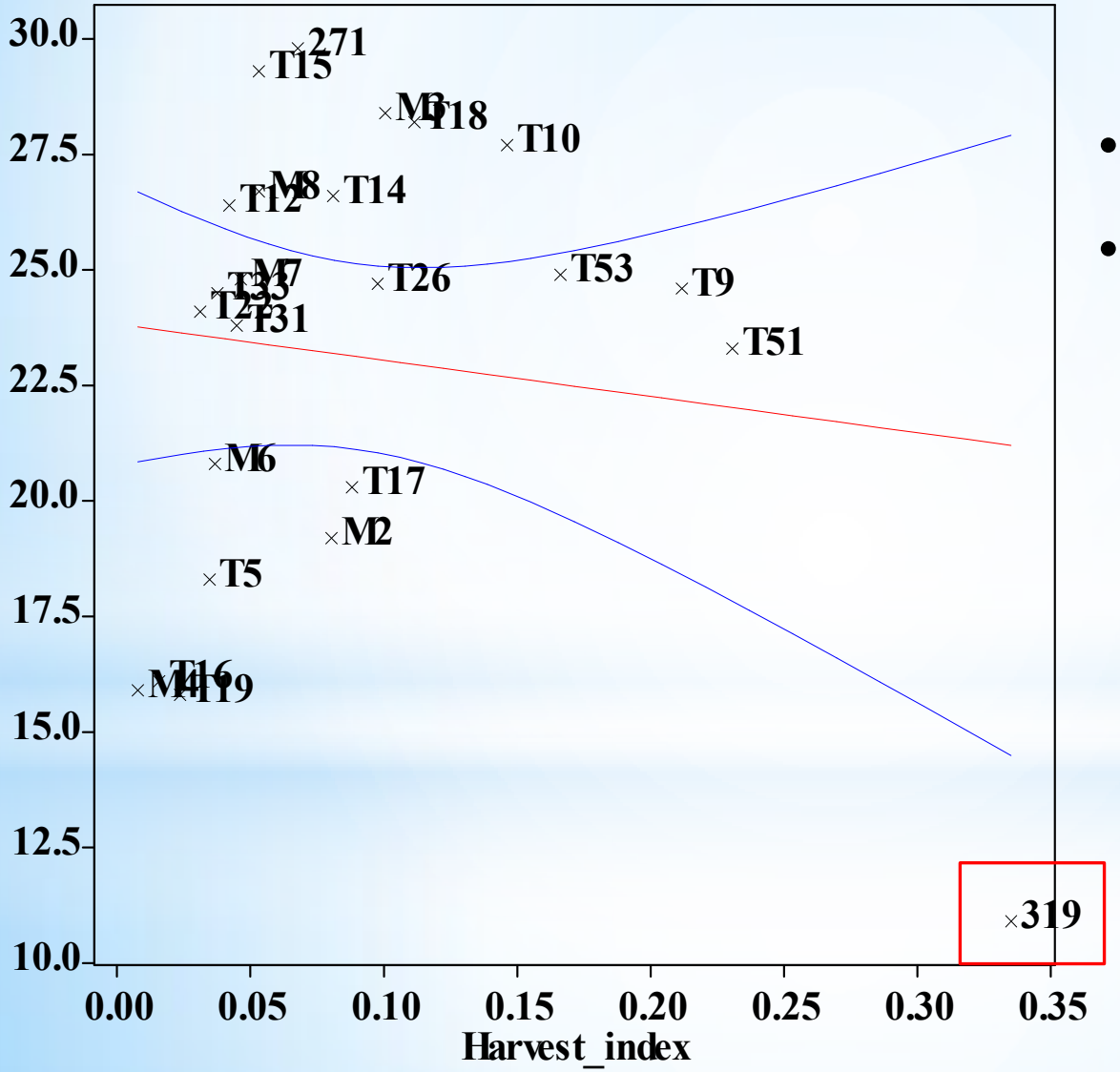
Fitted and observed relationship with 95% confidence limits



- Inverse relation-earlier flowering was associated with higher harvest index.
- 319 showed highest harvest index and earliest to achieve 50% flowering.

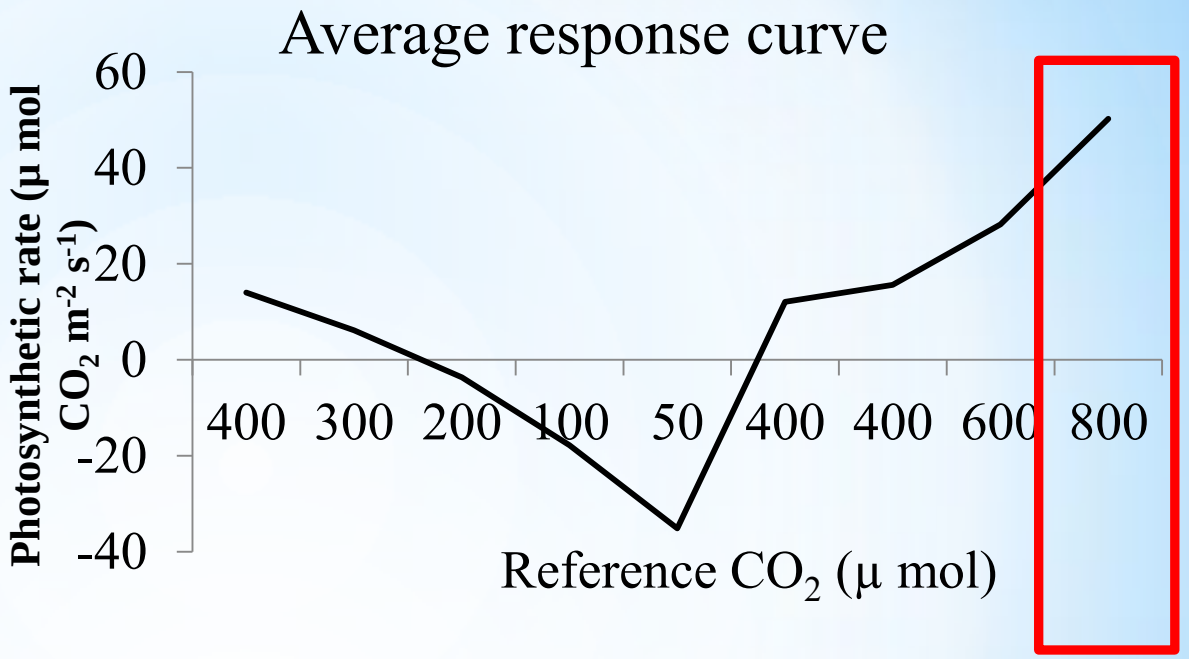
What if we relate harvest index to side branches?

Fitted and observed relationship with 95% confidence limits



- Not strongly correlated
- 319 showed highest harvest index and lowest number of side branches.

Accession	Photosynthetic rate at 800 µ mol CO_2
M2	*80.253
M3	*39.415
M4	33.527
M6	*51.790
M7	*45.031
M8	23.255
T5	*60.478
T9	*42.541
T10	*40.532
T12	*47.385
T14	*42.695
T15	*51.996
T16	58.757
T17	**38.411
T18	*47.015
T19	*66.572
T22	*83.760
T26	*39.415
T31	*53.486
T33	*70.653
T51	*37.286
T53	**25.326
319	**53.928
271	71.428



- Cernusak *et al.* (2011) showed photosynthetic responses to elevated CO_2–closely related to their capacity of nodule formation.

- Elevated CO_2 most significantly enhance photosynthetic rate of T22 and probably the harvest index (Liu *et al.*, 2012).

Summarizing morpho-physiological characterization

- Accession 319 was superior over other accessions in possession of high harvest index and reduced bushiness.

- Under the same growing conditions, significant differences between and within accessions would suggest that for future improvement we will need to select better accession and better material within the accession.

Transcriptome sequencing

RNA samples (Malaysian accessions)

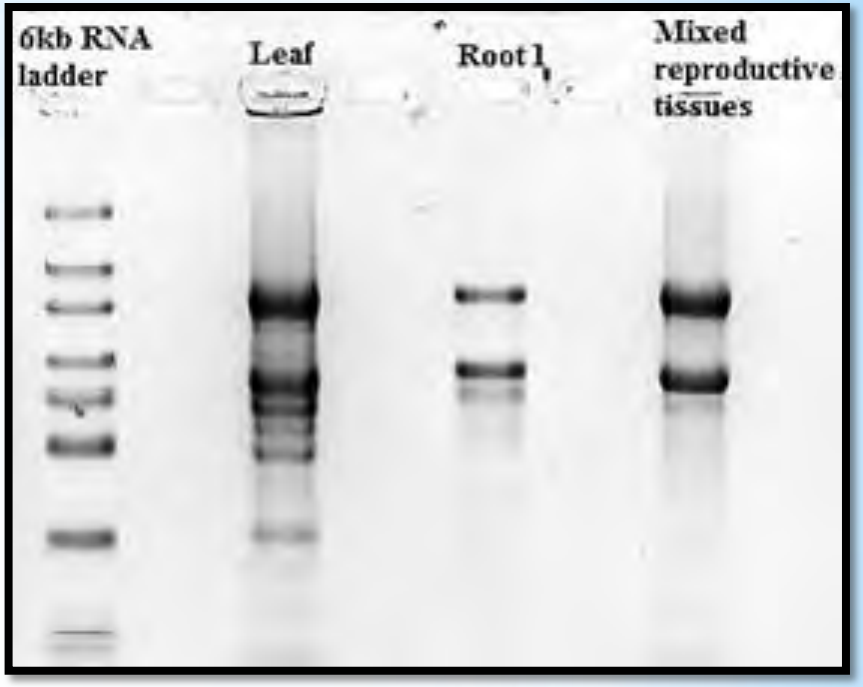
- Leaf
- Root
- Reproductive (pod, bud, flower)

Trizol Extraction

Paired end Mi-Seq sequencing

3857 SSR sequence loci detected

Genetic diversity analysis



Motif	Mono	Di	Tri	Tetra	Penta	Hexa
Number of SSRs	2103	738	786	29	10	191

Conclusion

Based on morpho-physiological evaluations:

- Variations exist between and within accessions – opportunity for future winged bean improvement programme.

- A number of accessions showed superior characters e.g. accession 319 was superior over the other accessions - highest harvest index, earliest flowering time and lowest number of side branches.

Combined morpho-physiological and genomic data will serve as resources for winged bean breeding programmes to increase productivity.

Policy Implications

- Winged bean is a multipurpose crop and has high nutritional contents-potential alternative crop for food and nutritional security.

- Indeterminate growth habit and lack of improved varieties – major production constraints.

- Improved varieties of winged bean will increase crop's popularity and elevate its importance for food and nutrition security.

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Bibliography:

- Mnembuka, B.V. & Eggum, B.O. (1995). Comparative nutritive value of winged bean (*Psophocarpus tetragonolobus* (L.) DC.) and other legumes grown in Tanzania. *Plant Foods for Human Nutrition, 47*, 333-339
- Khor, H.T., Tan, N.H. & Wong, K.C. (1982). The protein, trypsin inhibitor and lipid of the winged bean (Psophocarpus tetragonolobus (L.) DC.) seeds. Journal Science Food Agriculture, 33, 996-1000
- Cernusak, L.A., Winter, K., Martinez, C., Correa, E., Aranda, J., Garcia, M., Jaramillo, C. & Turner, B. (2011). Responses of legume versus non-legume tropical tree seedlings to elevates [CO2]. The American Society of Plant Biologists, 157(1), 372-385
- Liu, G., Yang, C., Xu, K., Zhang, Z., Li, D., Wu, Z. & Chen, Z. (2012). Development of yield and some photosynthetic characteristics during 82 years of genetic improvement of soybean genotypes in northeast China. Australian Journal of Crop Science, 6(10), 1416-1422
- Yoneyama, T., Fujita, K., Yoshida, T., Matsumoto, T., Kambayashi, I. & Yazaki, J. (1986). Variation in natural abundance of 15N among plant parts and in 15N/14N fractionation during N2 fixation in legume-rhizobia symbiotic system. Plant Cell Physiology, 27(5), 791-79
- Karikari, S.K. (1978). Characters in the selection of winged beans (*Psophocarpus tetragonolobus* (L) DC tolerant to drought. *Acta Hort. (ISHS), 84*, 19-22 http://www.actahort.org/books/84/84_1.htm