Development of photoperiod sensitive sorghum to mitigate climate risks in West-Africa

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Introduction

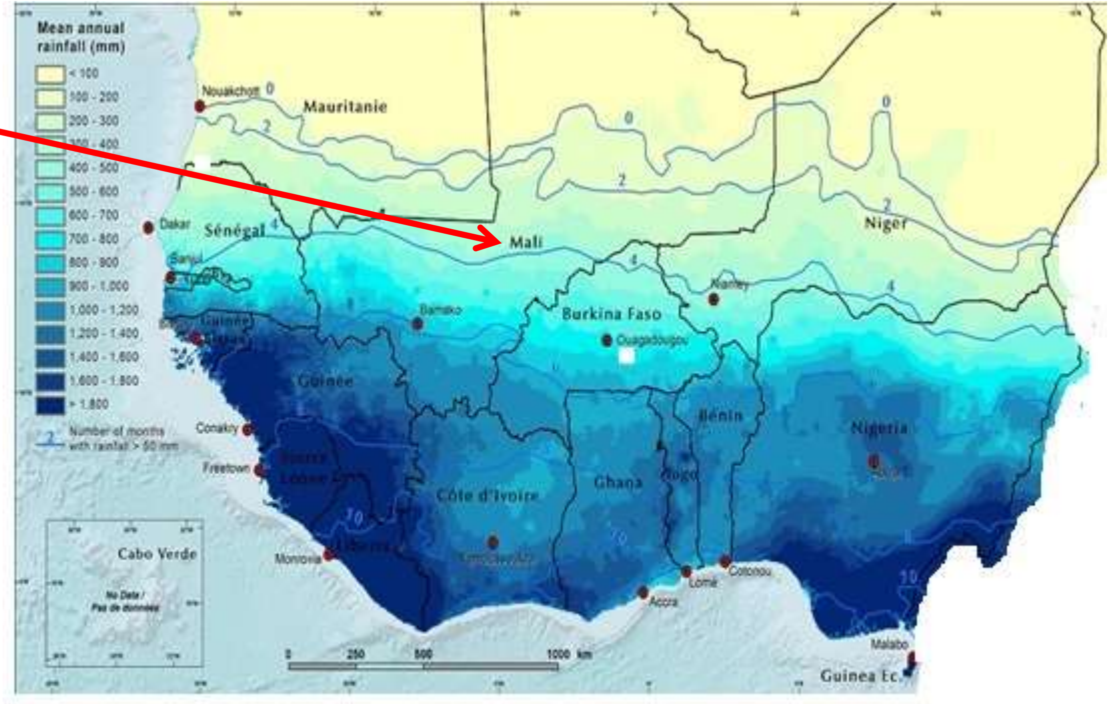
In West Africa, selection for early maturity has proven to be an inadequate goal as the problem is not the short growing season but its variability in both time and space.

Nowadays, the main objective of breeding programs has become the development of lines that flower at the most appropriate time in a given environment.

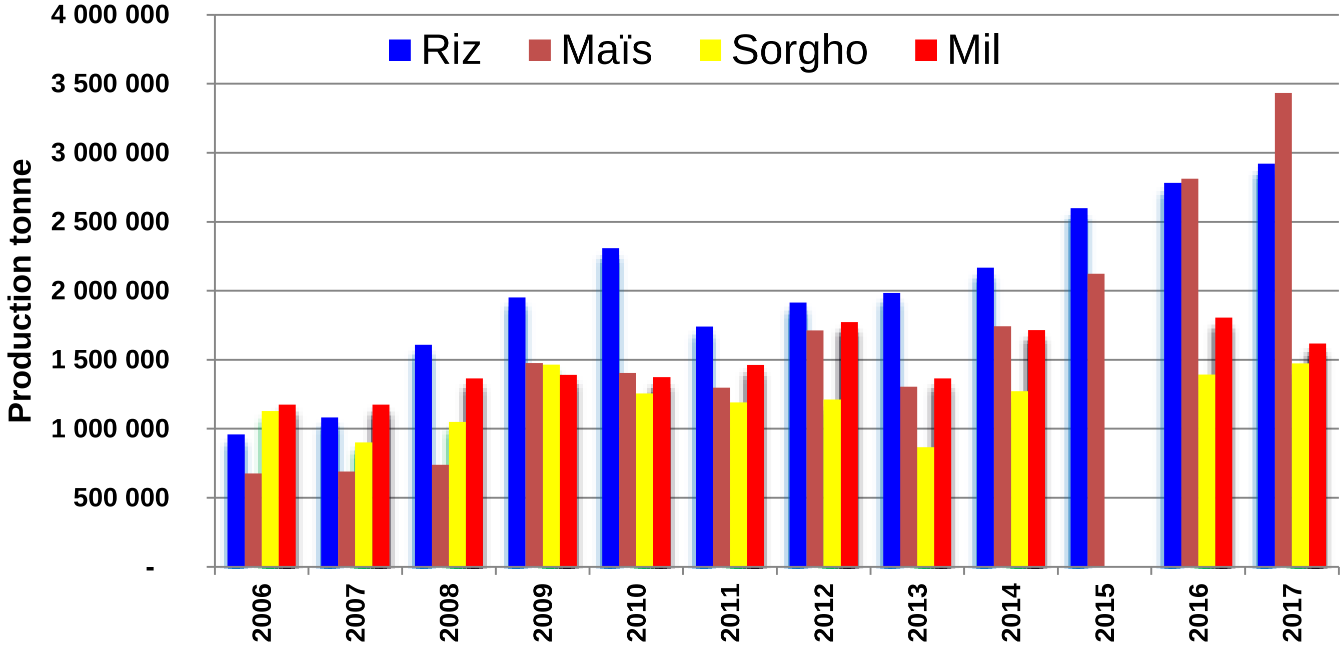
A multidisciplinary work, combining crop modeling and genetic analysis, using marker assisted breeding program intends to conciliate high yielding photoperiod sensitive varieties prone to sustainable intensification and climate smart agriculture approaches.

WEST AFRICA

MALI



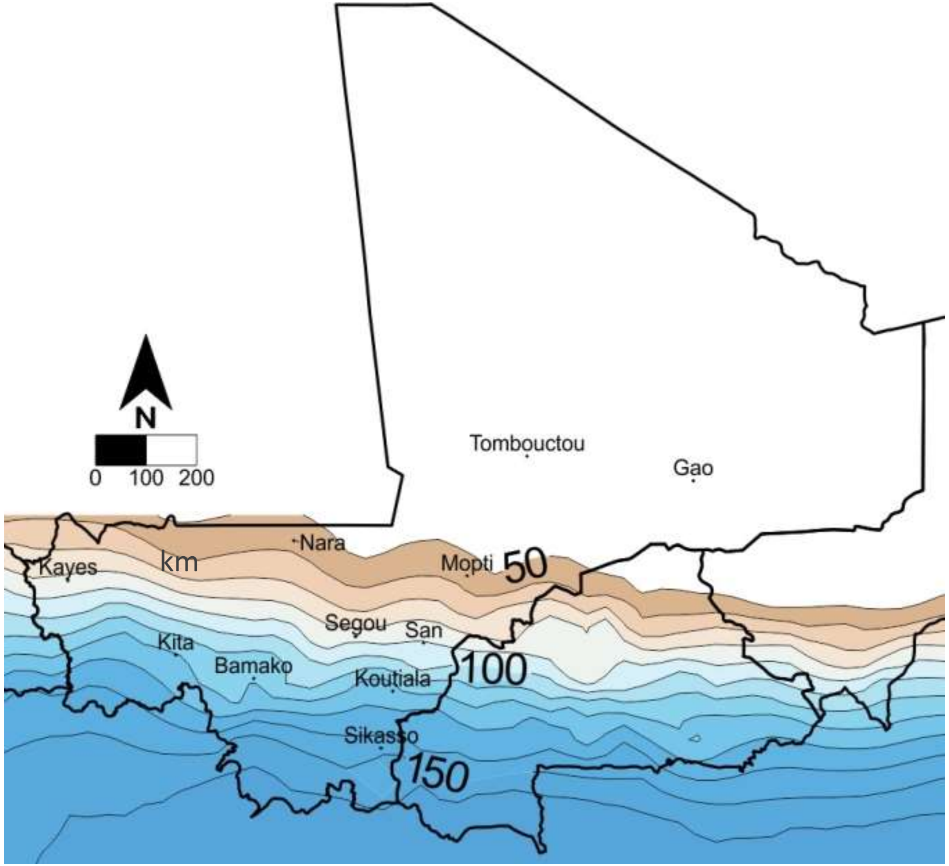
Sorghum production trend in Mali 2006-2017 (CPS-MA, 2017)



Climatic spatial variability

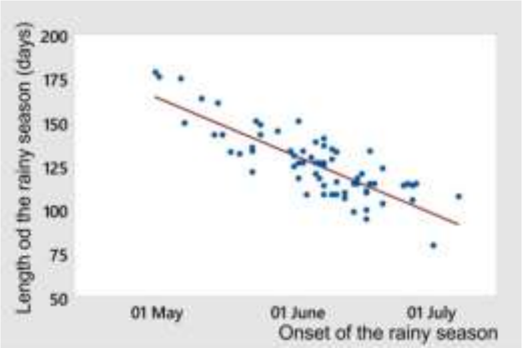
- West Africa semi-arid environment has always been very volatile in rainy season onsets and ends.

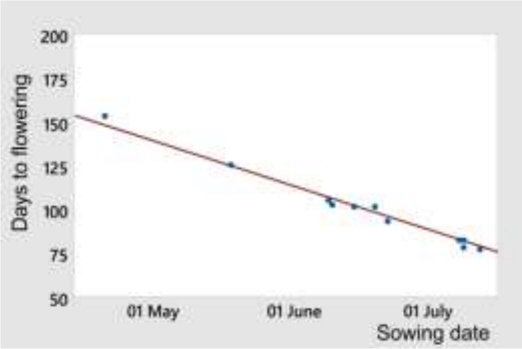
- Rainfall duration follows south (more) to north (less) gradients.



Duration (days) of the rainy season.

Climatic temporal variability causes Phenological variability





There is a also strong inter-annual relationship between beginnings and lengths of the rainy seasons.

An *early rainy season* onset will have a longer vegetative duration and therefore a higher yield potential (Sivakumar, 1988).

As a result, majority of farmers sow early photoperiod-sensitive landraces that bloom within 20 days before end of rainy season regardless of the sowing date (Kouressy et al., 2008).

An *early sowing* will result in a longer duration of vegetative phase.

Photoperiodism is a key trait to mitigate climate change

- In the wake of green revolution, option was to eliminate photoperiod-sensitivity to develop day neutral and early maturing varieties.
- This has been a poor choice as, in most part of WA, maturity before end of rainy season is often a disaster (insect, birds and mold complex) and maturity beyond rainy season faces terminal drought risks.

Effect of sowing date on sorghum

- Farmers now claim high yielding photoperiod sensitive variety better than their landraces.
- Marker assisted recurrent selection projects has provided some answers to the farmer needs in maturity and grain yield.

Current results are based on MARS and BCNAM projects

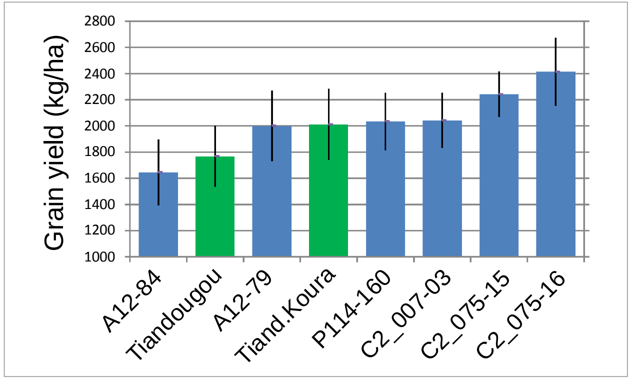
MARS project results

Improving sorghum productivity in semi-arid environments of Mali through integrated Marker Assisted Recurrent Selection-MARS

Keninkeni

Tiandougou

Derived line

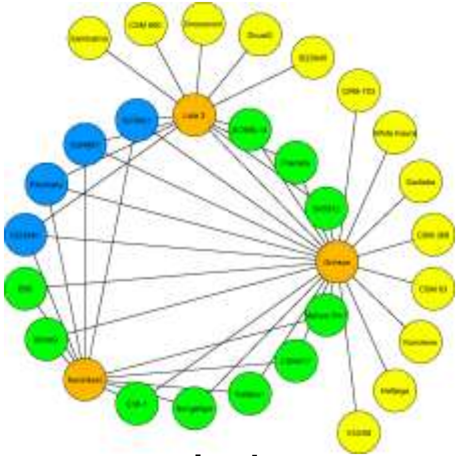


Compared with the best parent (Tiandougou), lines derived from marker-assisted selection resulted in an average gain of 650 kg/ha (37%).

Under productive environments, yield of best MARS lines reaches 4000 kg/ha on station and on best on farm test.

BCNAM project results

Development of sorghum with enhanced yield and grain quality for Sudanian zone of West Africa by a Back Cross-Nested Association Mapping approach-BCNAM



BCNAM populations were developed from 3 recurrent elite parents and 29 donor parents, resulting in 47 populations and 4717 BC1F4 families of which 3600 are genotyped.

Genetic analysis, combining association mapping and linkage analysis, detected many QTLs of interest:

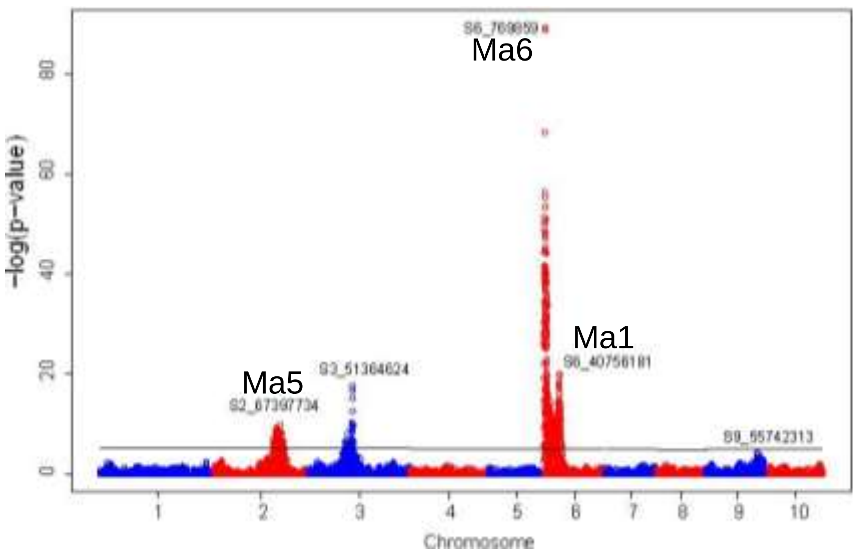
- Grain quality
- Grain yield
- Photoperiod sensitivity/maturity
- Resistance to foliar diseases
- Biomass productivity and stem quality

Genetic Control of Flowering

Several QTLs controlling flowering time were detected in MARS and BCNAM populations. Six major genomic zones were identified. Maturity genes fine tune photoperiod-sensitivity.

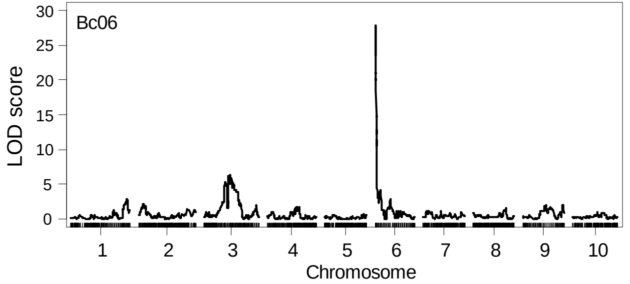
GWAS

Time to flowering Association mapping – BCNAM all populations

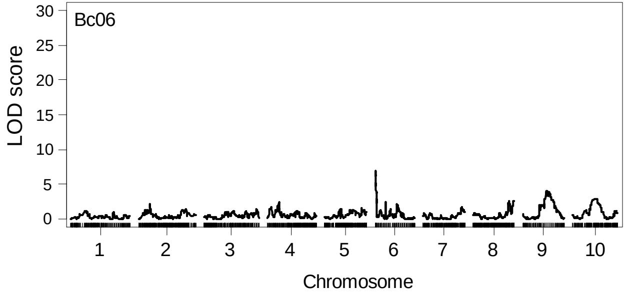


Linkage analysis

Maturity in normal cropping season (long daylength)



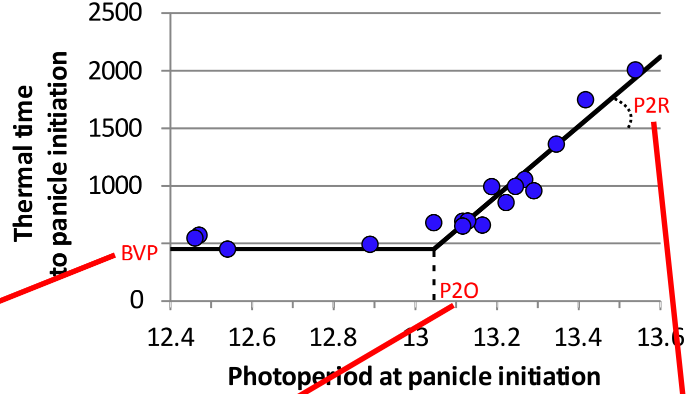
Maturity in off-season (short daylength)

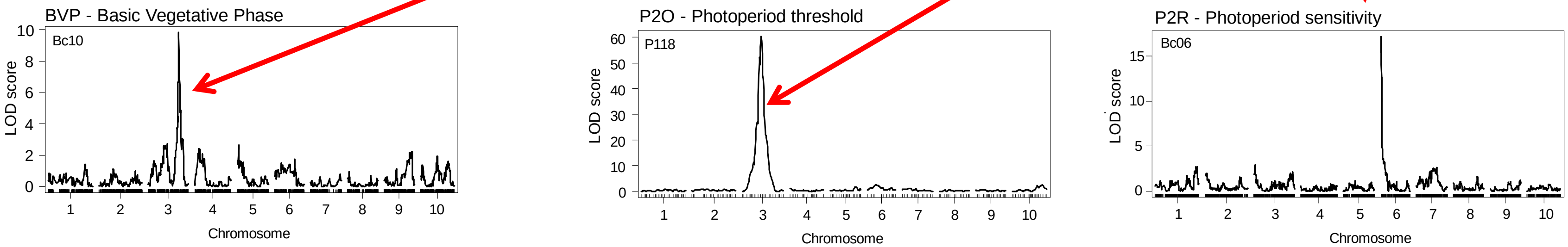


Crop modeling

Crop modeling, based on sorghum CERES model, provided an explanation of maturity QTLs effects.

Some QTLs modify photoperiod-sensitivity threshold (P2O), sensitivity to photoperiod variations (P2R) or the Basic Vegetative Phase (BVP).

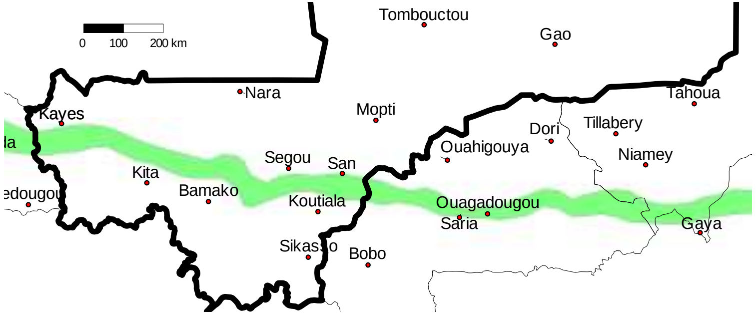


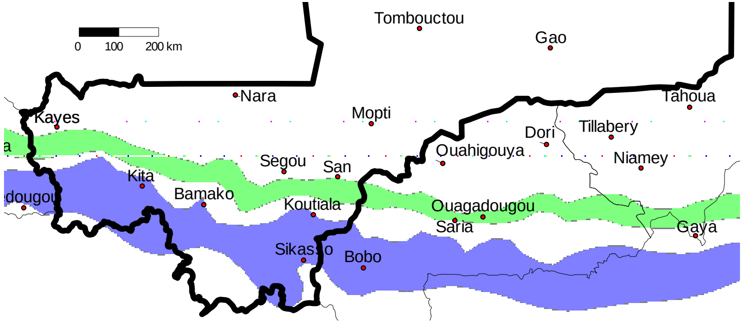


Model parameters are controlled by specific genomic regions.

Development of photoperiod-sensitive sorghum varieties

CERES model was used to predict the consequences of particular combinations of flowering time QTL on crop development.





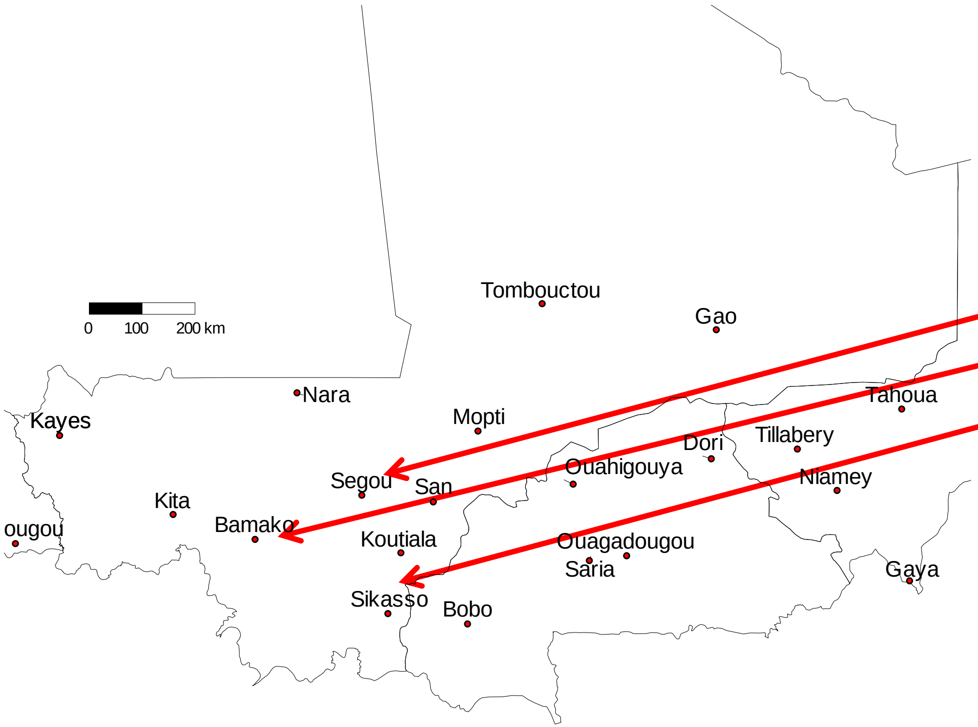
Optimal adaptation area (variety: Keninkeni)

Varietal adaptation zone was delineated by identifying areas in which flowering occurs at the correct time regardless of the sowing date.

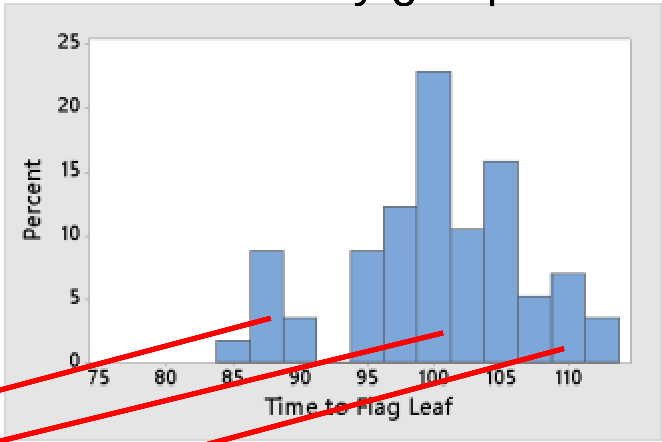
It is possible to predict the introgression effect of new alleles. Blue area corresponds to expected south shift of varietal adaptation zone by introgression of two maturity QTL.

Crop model led us to attempt the introgression of maturity genes alleles in MARS / BCNAM families to change varietal adaptation areas.

Progenies are currently being evaluated.



Maturity groups



(KK/Tiandougou)//(KK//IS15401)

These findings are valuable assets for breeding program to develop varieties specifically adapted to different climatic zones in West-Africa.

Conclusion

So far, it were thought that photoperiod-sensitive varieties were intended to low-yield environments. Our findings support existence of strong correlation between photoperiod-sensitivity and higher yields of new lines in West-Africa-Mali.

Integrating modeling and molecular genetics backed by intense phenotyping are major keys to conceive breeding ideotypes to mitigate climate change scenarios thus capitalizing on the prediction ability of ecophysiological modeling and on the precision of marker assisted breeding.

Sustainable intensification and Climate Smart Agriculture are closely interlinked concepts as improving climatic risks management provides the foundations for sustainable intensification.

Partners for Next steps

- Large MARS and BCNAM populations are available
- Pyramiding QTL while maintaining sensitivity to photoperiod, grain quality and yield is needed (500 -1200 mm);
- Study for deep understanding of QTL;
- Biomass composition and quality for livestock feeding
- On farm testing with seed companies, farmers' organisations and cooperatives.

Thank you to all of my partners

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