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Centre de coopération internationale en recherche agronomique pour le development
CIRAD
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Quantifying the morphological plasticity of plant response to AWD with regard to genotype characteristics and soil texture

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Plant response to AWD: initial screening

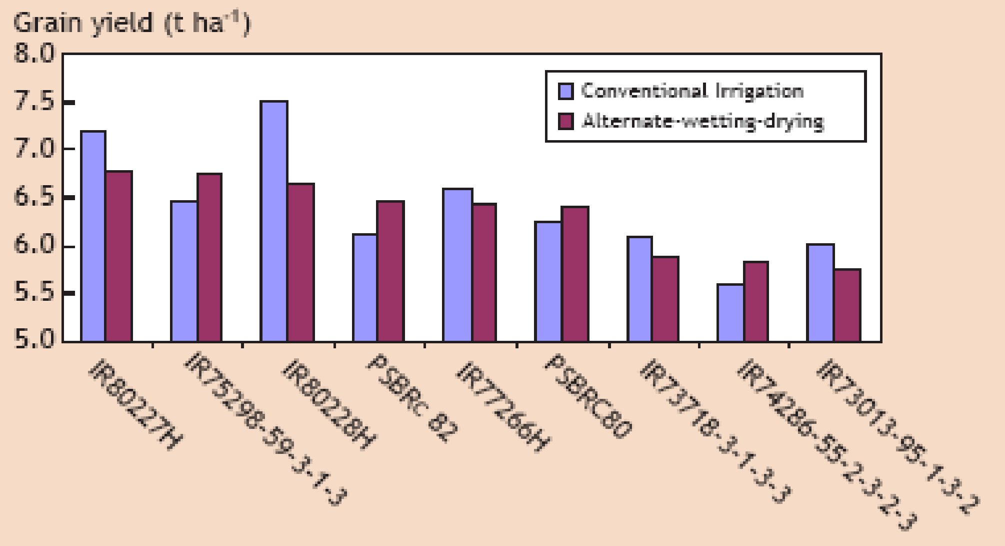
Breeding and screening in 2003 and 2004 (*Parminder Virk*):

The performance of 44 high-yielding genotypes (7 hybrids, 37 inbreds) was compared under:

- continuous flooding
- alternate wetting and drying (*the field was re-irrigated to 5 cm water depth after the water level had receded to 25 cm below ground*)

4 lines were selected for a wide range of plant response (*Parminder Virk*)**:**

- 2 likely adapted lines:
  - PSBRc80 (I4)
    popular elite variety for water saving
  - IR74-963-262-5-1-3-3 (I15)
    long crop duration inbred
- 2 likely susceptible lines:
  - IR64 (I2)
    popular elite and check variety
  - IR77266H (H10)
    short duration hybrid



Yield (t ha^{-1}) of nine promising inbreds and hybrids under irrigated and AWD conditions.

1 extra promising line was selected from aerobic trials (*Gary Atlin*):

IR78386H (H5), *short duration high yielding hybrid*

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Plant response to AWD: objectives and approaches

- **Objectives: to quantify plant response to AWD of contrasted genotypes**
- **Output: to identify some key (selectable) traits for AWD. Because this system requires high-yielding genotypes, it is believed that these traits shall be largely different from those selected for drought tolerance**
- **Approach: to characterize growing conditions in order to minimize confounding effects:**
  - Soil water availability to plants: genotypes have contrasted rooting system and uptake soil water at different rate ⇒ FTSW
  - Meristem temperature: soil temperature might be affected by water regimes (drainage periods) and might affect plant growth and development ⇒ thermal time
  - Controlled seepage: isolation of plots from one to another with plastic sheets installed all around the plots
  - Avoidance of spikelet sterility: no drainage during the flowering period

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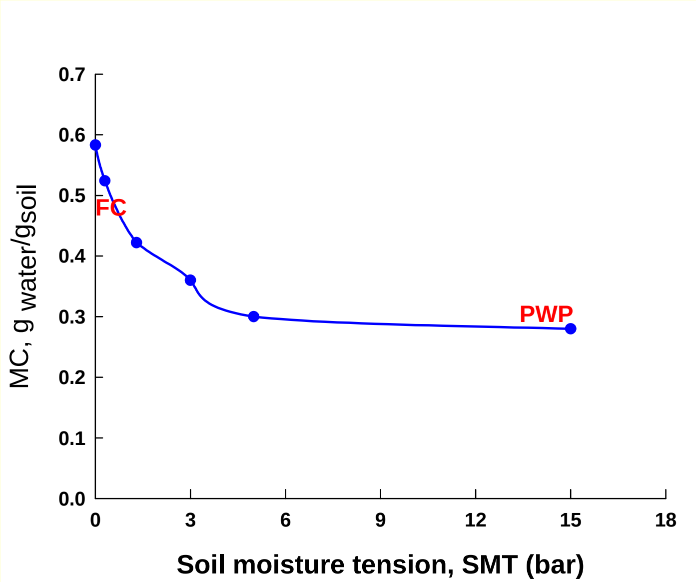
Plant response to AWD: objectives and approaches

- **Three levels of irrigation were set up (no drainage during 2 weeks at flowering and no lateral flow):**
  - continuous flooding (CF) with 5 cm water depth
  - alternate wetting and drying (AWD_{mild}): irrigation when soil water potential reached - 30 kPa at 15 cm depth (tensiometers)
  - alternate wetting and drying (AWD_{strong}) irrigation when soil water potential reached - 60 kPa (tensiometers) at 15 cm depth

- **Thermal time (TT) was calculated (soil and canopy temperature) to integrate the differences of temperature between plots**

- **Optimum fertilizer inputs were applied. Weeds, snails, insects, rats and birds were highly controlled.**

Characterizing soil water availability

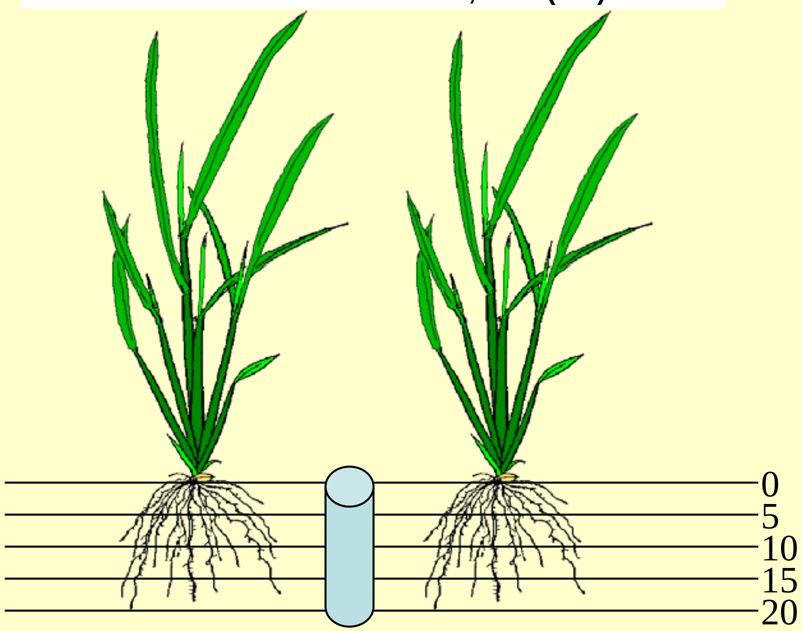


Undisturbed soil core samples collected at different soil layers were saturated by capillary rise and subjected to different pressures in the lab. Samples were weighed before and after oven-drying at 105 °C. Moisture content at the different pressures were calculated and plotted

During the experimental season, soil samples were collected at different times during the imposition of the AWD treatments to determine the actual soil water content

FTSW = Fraction of Transpirable Soil Water

$$FTSW_{layer} = \frac{ASW - PWP}{TTSW}$$



ASW = Actual Soil Water

Permanent Wilting Point, PWP = Moisture content at 15 bars

TTSW = Total Transpirable Soil Water

where;

TTSW = FC-PWP

Field Capacity, FC = Moisture content at 0.33 bar

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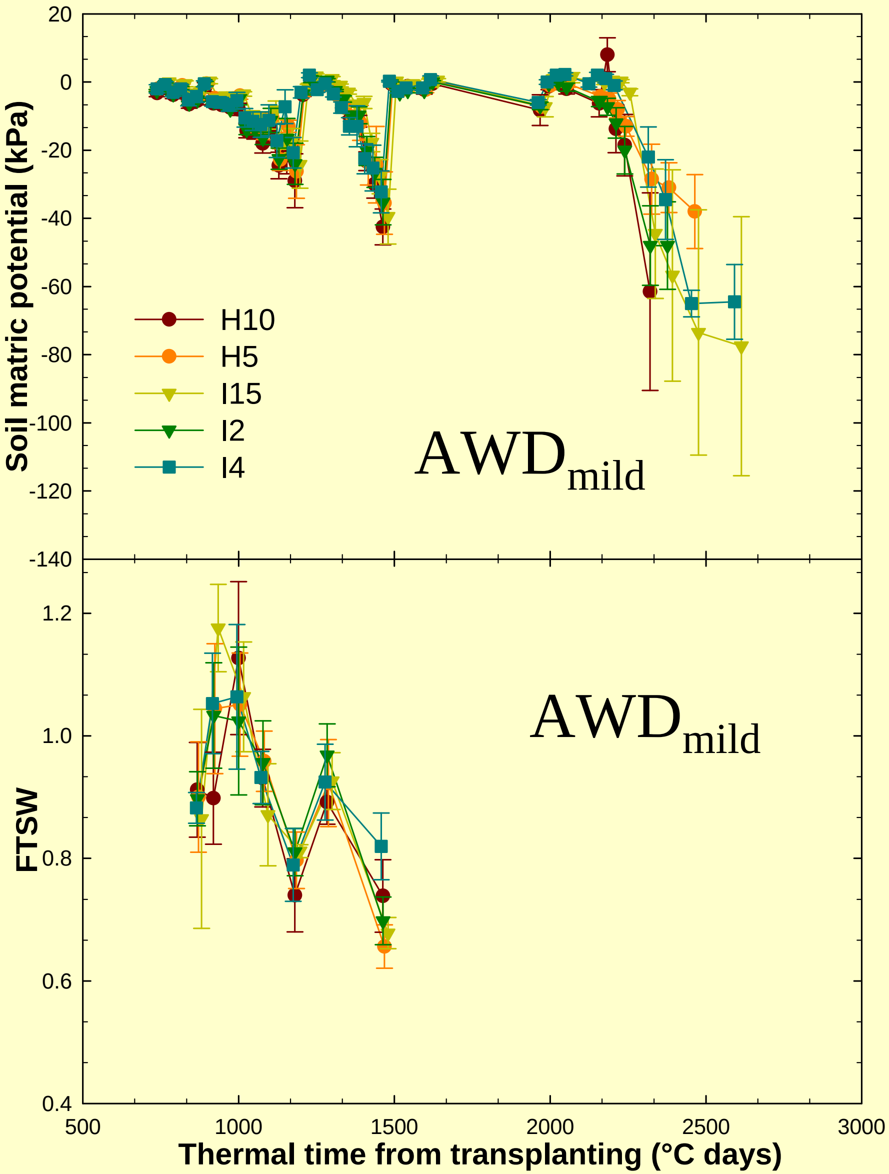
Characterizing soil water availability



Because of the high rainfall, no drainage cycle occurred before panicle initiation, and only 2 cycles occurred between PI and flowering

The genotypes appear to have dried the field at about the same rate (soil matric potential), however, an appreciable variability in the availability of the soil water (FTSW) was reported.

Stomatal conductance was missed because of equipment failure

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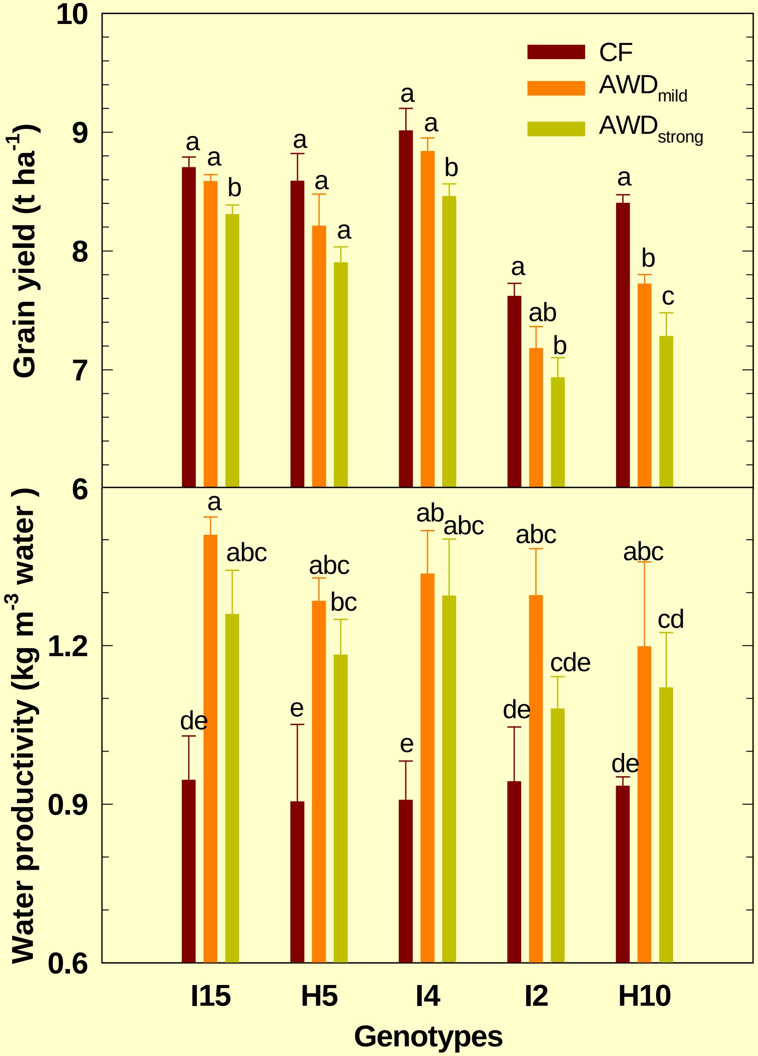
Final performance, grain yield and water productivity

Water input was calculated as the sum of rainfall and irrigation (flow meter)



The relevance of AWD as a system to maintain grain yield and increase water productivity is confirmed

Grain yield of high-yielding genotypes under AWD strongly related to that under CF, but significant differences between lines:
Grain yield of H10 was significantly reduced under AWD_{mild} while that of I2 was appreciably reduced and that of the other 3 were not affected

Water productivity was the highest under AWD_{mild}, and was consistently lower under AWD_{strong} where grain yield of most of the genotypes was significantly reduced

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Dry matter distribution at maturity: variability in culm vigor?

Gen	Practice	ShDw g m^{-2}	Ptil m^{-2}	GrDw g pan^{-1}	HI
I15	CF	1694 a	255 a	2.94 a	0.51a
	AWD_{mild}	1619 a	269 a	2.74 ab	0.49a
	AWD_{strong}	1670 a	265 a	2.69 b	0.49a
H5	CF	1627 a	314 a	2.35 a	0.55a
	AWD_{mild}	1659 a	319 a	2.21 ab	0.54a
	AWD_{strong}	1542 a	316 a	2.15 b	0.53a
I4	CF	1616 a	313 b	2.47 a	0.54a
	AWD_{mild}	1555 a	331 a	2.30 b	0.52a
	AWD_{strong}	1541 a	320 ab	2.27 b	0.53a
I2	CF	**1523 a**	360 a	1.82 a	0.50a
	AWD_{mild}	**1350 b**	369 a	1.67 b	0.46b
	AWD_{strong}	**1309 b**	369 a	1.61 b	0.49a
H10	CF	**1547 a**	356 a	2.03 a	0.56a
	AWD_{mild}	**1424 a**	354 a	1.88 b	0.53a
	AWD_{strong}	**1368 a**	354 a	1.84 b	0.53a

A strong reduction in shoot dry matter was reported for the susceptible genotypes

Shoot dry matter of I15 appeared stable despite contrasted water regimes

Panicle number (stable), grain dry weight per panicle (reduced) and harvest index (poorly reduced) varied quite consistently across lines

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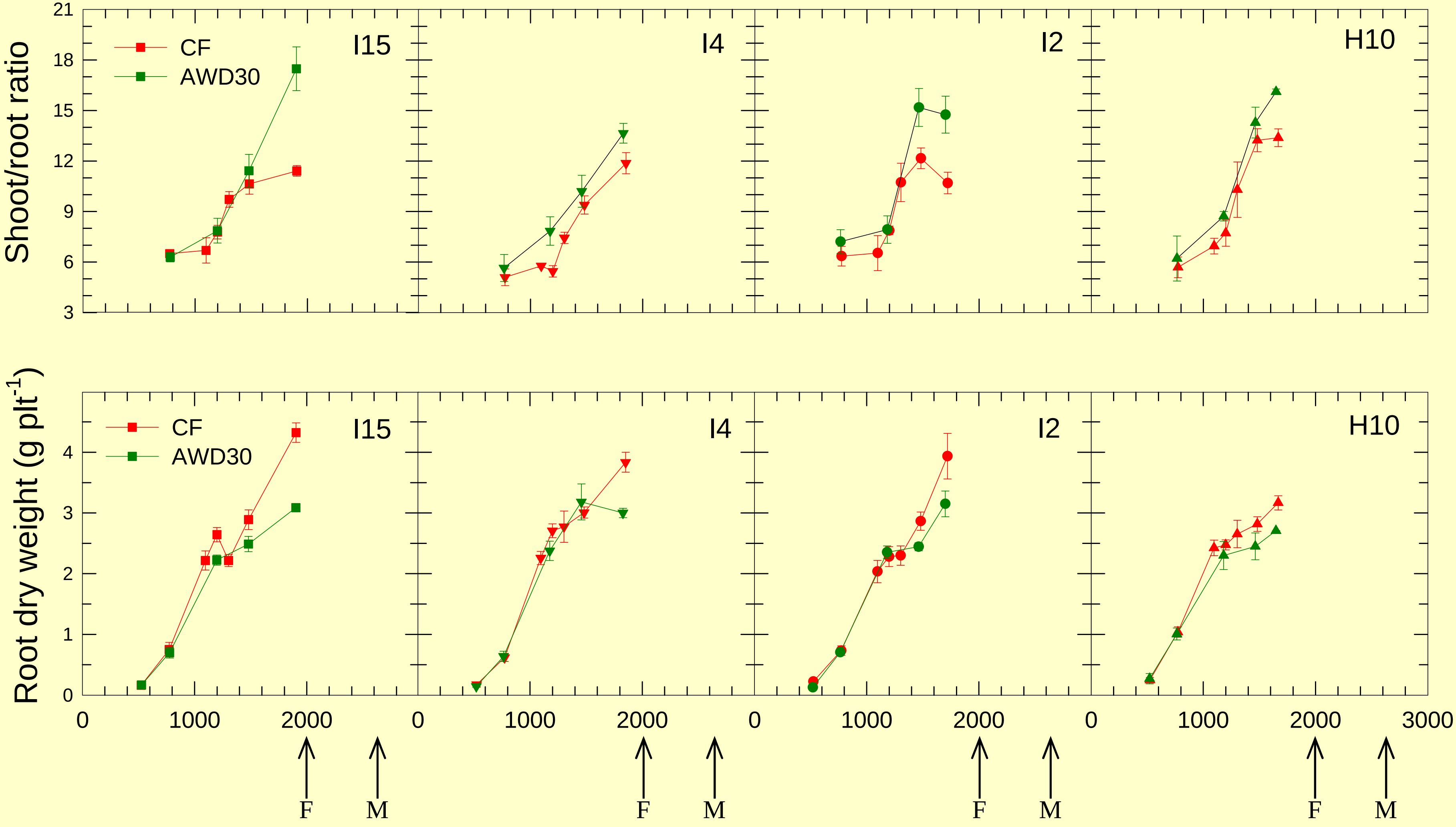
Dry matter partitioning between shoot and root: priority to root?



Increase in shoot/root dry weight associated with a significant reduction in root dry weight for all genotypes
Variability across genotypes?

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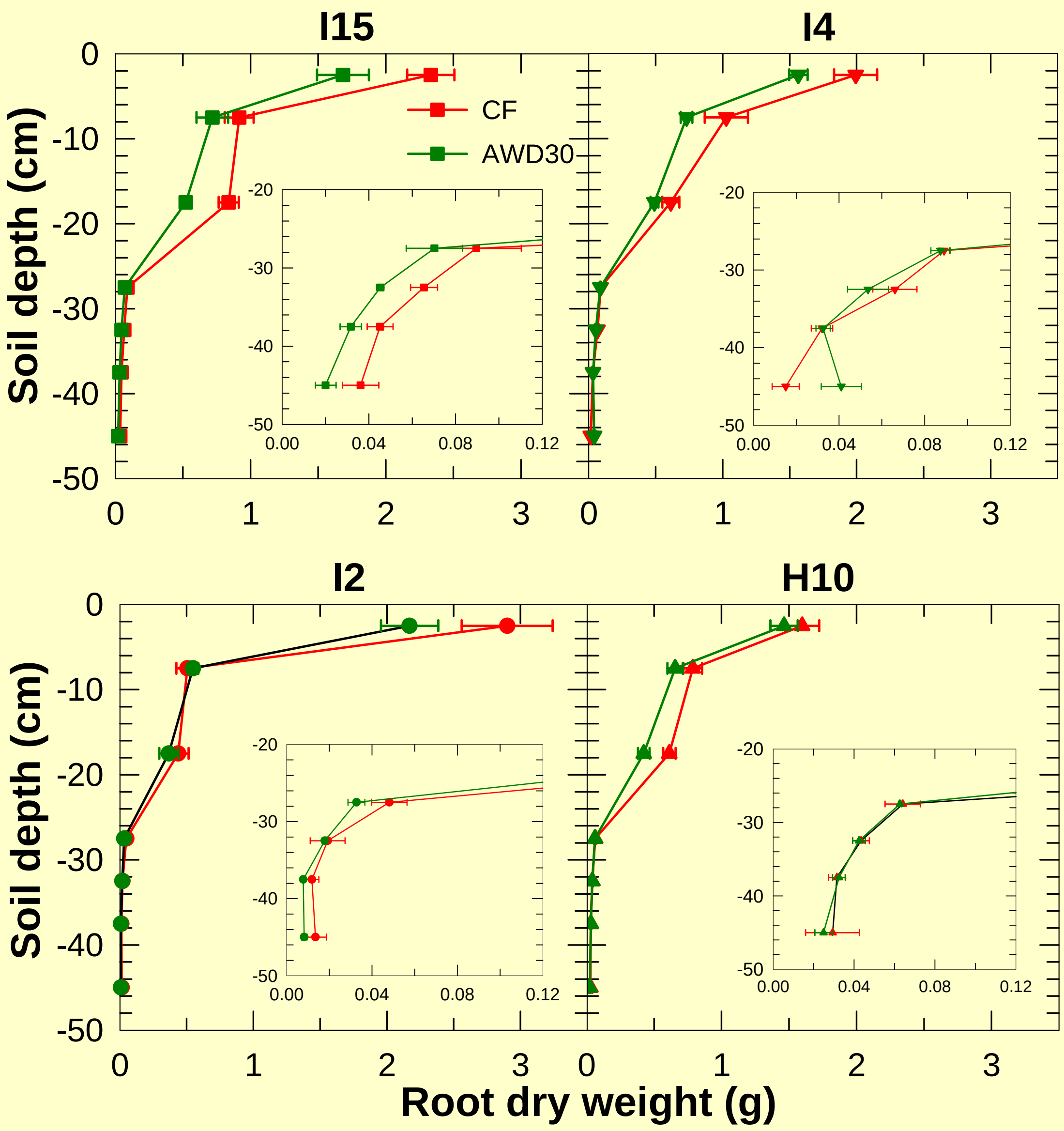
Root dry matter distribution: variability in rooting depth in time?



Comparing root distribution with soil depth at flowering

High root dry matter of I2 at the soil surface and low dry matter in deeper layers without impact of the water regimes

Larger root dry matter of I15 at deep layers in favorable conditions, particularly at layers below 30 cm.

Significant reduction in root dry matter of I15 at all layers under water deficit

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Dry matter distribution at maturity: variability in culm vigor?

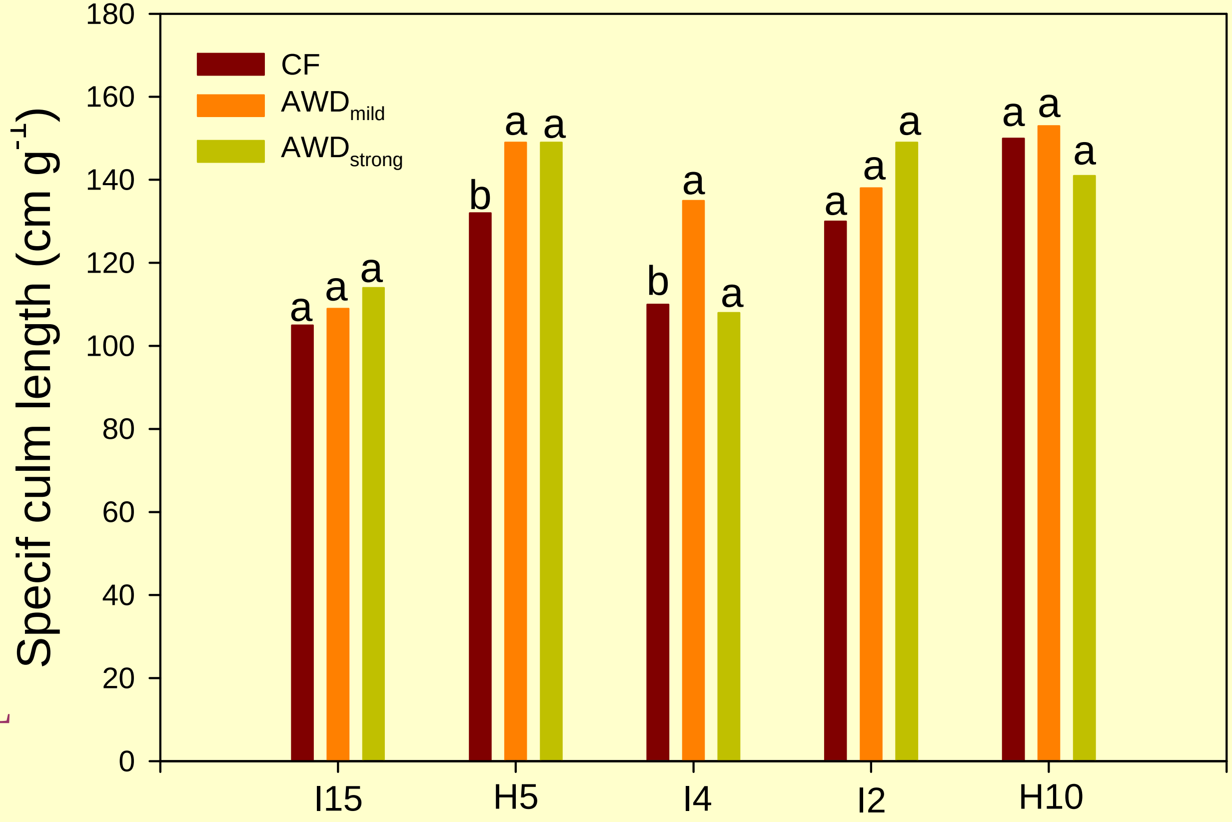
Measuring the culm length and dry matter of the same tillers

Specific culm length:

$$SCL = \frac{\text{culm length}}{\text{culm dw}}$$

Significant increase in SCL (= reduction in culm vigor) was reported for promising genotypes like H5 and I4, particularly under AWD_{mild}

No significant increase in SCL was reported for I15 whose shoot dry matter at maturity was stable across practices



Higher dry matter remobilization from the culm may compensate the lower shoot dry matter accumulation

Preliminary conclusions

- **Strong increase in water productivity when irrigation occurs at – 30 kPa (no further increase with – 60 kPa) with grain yield almost non affected**
- **Increase in shoot/root ratio consistently observed as a response to water deficit to the detriment of root dry weight**
- **Two main features can support the higher performance under AWD**
  - A constitutive deep rooting system, particularly below 30 cm, with apparent significant reduction in root dry matter allocation under water deficit at all depths
  - An inductive dry matter remobilization from the culm to the panicle during grain filling

This needs to be confirmed in a wider range of genotypes with more drainage periods

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Workplan 2008:
1. Quantifying the morphological plasticity under AWD and identifying key traits for breeding: IRRI dry season 2008

- **Needs from the former experiment:**
  - to focus on AWD_{mild} (AWD_{strong} reduced water productivity)
  - to increase the number of drainage periods starting 1 week after transplanting (fortunately the weather conditions will help)
  - to increase the number of genotypes under study in order to confirm the previous observations and increase the range in plant response
  - to increase the number of plant response to characterize (stomatal conductance *vs.* FTSW)

- **Would an opposite plant response (shoot/root ratio) be observed under water saving and under drought?**

- **Would the contrasted rooting system trigger contrasted dynamics of soil water drying?**

- **Would high performance under AWD due to the maintenance of leaf area thanks to deep rooting system and/or to plastic sink regulation (decrease in root and culm dry weight)?**

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Workplan 2008:
1. Quantifying the morphological plasticity under AWD and identifying key traits for breeding: IRRI dry season 2008

- **5 former genotypes of the previous experiment:**
  - 3 likely adapted lines: PSBRc80 (I4), IR74-963-262-5-1-3-3 (I15), IR78386H (H5)
  - 2 likely susceptible lines: IR64 (I2), IR77266H (H10)
- **2 IR64 NILs from Dr Kobayashi with contrasted yield performance but high SCL at maturity (which may support high sink regulation even though no performance under control conditions was provided)**
- **1 promising aerobic line from Dr Kumar**
- **1 high-yielding hybrid with high SCL at maturity**
- **1 inbred with high culm storage capacity**

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Workplan 2008:
1. Quantifying the morphological plasticity under AWD and identifying key traits for breeding: IRRI dry season 2008

- **Plant measurements:**
  - phenology, tiller and leaf emergence
  - leaf area production
  - shoot/root ratio, root distribution with regard to soil depth, shoot dry matter allocation with regard to above-ground organs (blade, sheath, culm, panicle), leaf and stem vigor,
  - concentration of soluble sugar and starch in the plant tissues
  - stomatal conductance

- **Growing conditions characterization:**
  - Climate data and soil and canopy temperature
  - Soil water content and availability

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Workplan 2008:
2. Quantifying the impact of soil texture on plant growth, grain yield and water productivity under AWD and contrasting seedling age: farmers' rice fields in Tarlac region, dry season 2008

- **Water tension in the case of researchers, or depth of available soil water in the case of farmers, are used to drive irrigation under AWD without any consideration of soil texture.**
- **Soil texture may, however, affect**
  - plant growth in favorable water conditions, particularly root distribution and shoot to root ratio
  - plant sensitivity to soil water tension, due to variability in soil water conductivity and in the rate of soil drying.
- **Transplanting young seedlings was reported to increase significantly grain yield and reduce the whole crop duration, but increase the duration of growth in the main field and then the total water use.**

The plant response to AWD and age at transplanting and the associated water productivity may vary with regard to soil texture and genotype characteristics

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Workplan 2008:
2. Quantifying the impact of soil texture on plant growth, grain yield and water productivity under AWD and contrasting seedling age: farmers' rice fields in Tarlac region, dry season 2008

- **Objective: to quantify the water use and water productivity**
  - under water saving technologies with regard to soil texture
  - under flooded conditions with regard to seedling age at transplanting

- **Output: to better design AWD management and seedling age with regard to soil texture**

- **Approach: to work in fields with contrasting soil texture**
  - located as close as possible to each other (considering then similar climate conditions with only one weather station),
  - with the same seedlings at transplanting (one single nursery),
  - with the same planting design (same hill spacing and plant density),
  - with the same water management (tensiometer or porous cylinder driven)
  - with optimum N management (SPAD driven)
  - with genotypes with contrasted sink capacity (one hybrid and one inbred)

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Workplan 2008:
2. Quantifying the impact of soil texture on plant growth, grain yield and water productivity under AWD and contrasting seedling age: farmers' rice fields in Tarlac region, dry season 2008

- **Soil texture in 7 fields ranges from clay, silty clay loam, silt loam, loam and loamy sand**
- **Two distinct genotypes, PSBRc80 (elite line) and IR78386H (hybrid rice)**
- **Four distinct crop management:**
  - continuous flooding (CF),
  - farmer's practice (FP) as advised by IRRI water scientists (irrigation whenever the level of available soil water will be as low as 20 cm deep
  - tensiometers driven irrigation (AWD) whenever the tensiometer at 15 cm deep will be as low as 30 kPa
  - young seedlings transplanting under continuous flooding (YS).

Workplan 2008:
2. Quantifying the impact of soil texture on plant growth, grain yield and water productivity under AWD and contrasting seedling age: farmers' rice fields in Tarlac region, dry season 2008

- **Plant measurements: shoot and root dry matter, shoot partitioning into blade and stem, dynamics of tiller and leaf emergence, grain yield and yield components**
- **Growing conditions: irrigation and rainfall, water retention curve of each field, dynamics of the root profile and of the soil water content at several soil depths, weather station**

Workplan 2008:
3. Quantifying plant traits in collaborative experiments under AWD

- Tillering dynamics (and leaf emergence?) in the nursery and in the field with contrasting seedling age at transplanting (Dr Furukawa)

- Tillering dynamics and stem vigor (at flowering?) and maturity with IR64 NILs under AWD (Dr Kobayashi)

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