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The Drought Environment: Physical, Biological and Agricultural Perspectives

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Abstract: Drought has many meaning in relation to crop production. These rang from: statistical (say, the lowest decile of annual rainfall) to a meteorologist; through yield being limited by too little water to an agronomist; to sudden severe water deficits to many molecular biologists. To a farmer, the corresponding management issues, respectively, are risk management (how bet to manage a meteorologically drought prone farm over several years), how best to match cultivar and agronomic operations to the developing growing season and how best to minimize possible major damage to (say) floral fertility induced by severe water deficits during flowering. All these definitions and the issues they imply are relevant to improving crop production when water is limiting. How can scientists best help? The answers depend on the scales (temporal and spatial) being addressed. Agronomist and breeders, interacting, can help improve components of seasonal water balance in the field, for example, minimizing evaporative losses from the soil surface by better matching the development of a crop to its environment. Physiologist, biochemists and molecular biologists can help by identifying ways of improving the competence of particular organs. A promising target is floral infertility resulting from water deficits, which results from lesions in tissue and cellular and molecular processes. Choosing problems whose solutions will have implications in the field and attractive to farmers requires knowledge of what is important in the filed.

Key words: Agriculture, biological environment, crop production, drought, interdisciplinary co-operation, physical environment

INTRODUCTION

Drought is an evocative term. It comes with connotations of severe financial hardship among farmers in rich countries, to malnutrition, even famine, among farmers in poor countries. If prolonged it can lead to major social upheaval, mass migration. And desertification, not only in the sense that the affected region is deserted by its former inhabitants, but also because over-farmed land may become so degraded that it can no longer support human habitation even when the prolonged drought is over.

These are the well-known connotations of the term. In the scientific and technological worlds it has gained several more meanings in addition to its primary one of there begin too little rain. This variety of meanings often results in debates being at cross purposes. For drought means different things to different practitioners depending. Largely, on their time scales of interest. It is especially important at an interdisciplinary meeting such as this, which ranges so widely in its discussion of drought. That we are carefully explicit about what we are talking about.

Table 1 summarizes how various practitioners. With time scales of interest ranging from hours to millennia, commonly view issues they see as important in relation to drought. This rang of time scales is matched by a corresponding rang in spatial scales. From molecules, through organelles. Cells, organs, plants and communities. To ecosystems. The two longest time scales are contextual for the purposes of this meeting. They cover phenomena that are beyond our influence. But in so doing give us as.

Agricultural and plant scientists, a cleaner idea of what we can influence. The longest time scale, that of millennia, deals with major climate changes that have affected human population and ecosystem. These changes are addressed by Araus *et al*. (2007) and for the Mediterranean region. With both broad-ranging arguments and scholarly detail, by Grove and Rackham (2001). Events at this time scale are of great political and administrativeinterest these days because of the insights they can give us in to how to understand and cope with major climatic change that seems to be upon us.

The next time scale, of a decade to century or two, concems historians. Geographers. Relief agencies. It deals

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Table 1: Drought and significance (Passioura, 2002)

Practitioner	Time scale of interest	Common meaning of drought	Significance
Geologist palaeontologist	Millennia	Aridity	Major climatic change
Historian geographer relief agency	A decade to century or two	Sequence of many years of low rainfall	Migration desertion famine
Meteorologist farmer insurer	Years	Rare event (say, the lowest decile of seasonal rainfall)	Risk management
Farmer agronomist crop physiologist breeder	Week to months growing season	Yield strongly limited by water	Water productivity
Plant physiologist	Days	Post not watered	Mild shok survval
Biochemist molecular biologist	Hours	Rapid desiccation sudden exposure to strong osmotical	Severe shock survival

with drought that are so long and severe that they cause major social disruption. If not famine. They have especially affected some pioneer societies that have been misled by a run of wet years into rapidly developing a hitherto uncultivated region. The subsequent return to a series of years with average or below average rainfall leads to severe hardship and at least partial abandonment. The opening up of the great plains of the USA in the 1880s. Inspired by the fallacious slogan of the Nebraskan land speculator Charles Dana Wilber that rain follows the plough. Is a classic example. On the other side of the Globe and at about the some time. The ill-advised expansion of the agriculture in to the semi-arid plains of the South Australia (Meinig, 1962) was followed by a similar disaster and retreat of the line of settlement. We are slow learners. The Great of the USA suffered again in the 1930s during the dustbowl era (Worster, 1979). And it was the impact of that dust on urban populations that probably created the political will to find more lasting solutions. But it is not only pioneer societies that have been affected. Overpopulation of already well-settled regions. As with the tragedies in sub-Saharan Africa over the last few decades. Leads to even worse problems. Compounded as they are by political turmoil.

The first two rows in Table 1 covering events occurring over a decade to millennia. Provide context for this meeting. But are well outside our collective expertise to deal with. It is the next two time scales. From one to several growing seasons, which relate to the ultimate focus of this meeting. These are this time scales at which farmers operate. And therefore, these are the time scales at which our efforts have to make sense.

DROUGHT IN RELATION TO FARM MANAGEMENT

To a farmer, drought is but one of a large number of risks that he or she must manage. As a risk. It is a statistical idea-say, the lowest decile or two of water supply for the growing season or the Palmer Drought Severity Index (Hyes, 2006). It is an idea that is in practical use by insurers and that may well be paramount in farmer's mind in a given season. But farmers face many other risks to production that may be of comparable importance. These include weeds, diseases (pathogenic fungi, bacteria, nematodes, or viruses). Herbivory (by insects, mites, snails). And various other type of weather damage (frost, heat, sprouting, loading, waterlogging). In the face of this list of potential disasters, good farmers say that they prepare for the worst but hope fore the best.

Taking a more specific view of drought then this statistical one. It is common for potential crop yields to be limited by water in most years in many environments. The challenge then is to produce more from the given limiting water supply, to produce more crop per drop to use the slogan of the CGIAR Challenge Program on water and Food. It is this goal that is addressed by many of the papers at this meeting. From a farmer's point of view, though, the intrinsic ability of plant to use water most effectively. Though important, is secondary to many other considerations. Experience on the farm is that crop yield even in seemingly strongly water-limited environments. may not be very responsive to water supply except.

In the driest years (RockStröm and Falkenmark, 2000; Passioura, 2006) weeds, disease, insects and any other of the rest of the problams listed above many be affecting yield much more than water supply. Indeed, good farmers manage their land with an eye not only to the current year.

But to the next several as well. Many aspects of crop management, such as choice of crop sequence or stubble management, are much concerned with reducing the risk of future problams with weeds and diseases as with getting the best productivity in the current year.

Operationally, farmers are as much affected by the timing of water deficits during a season by the total seasonalwater supply. Different problams are created by water deficits at different main development stages of a crop, that is at sowing establishment, tillering or branching, flowering or grain filling. The ferquency of water deficits at each of thesevaries with climate-whether this beclassified very boradly into perdominantly latitudinal zonesas in Fischer and Tumer (1978), or into the more finelly classified mega-environments used by CIMMYT to guide its breeding programes in wheat and maize.

However, deficits can occur in all zones at all growth stage, Farmers have developed various way of managing risk associated with episodes of water deficits within a season. Many of these techniquse are effective and are often outside the purview of plant scientists. For example, if the soil profile is wel-charged with water, but the top soil is nevertheless dray at optimal sowing time, sowing deeply me enable the seeds to access enough water to germinate and enable the roots to access the deeper water. This is often a viable agronomic option. However, if the seed is a semi-dwarf wheat and is coverd by too much soil, the semi-dwarf coleoptile will not reach the surface and although germination may be good, establishment will be poor and so will yield. Thise ancillary problem is one that we canm help slove, once we are alerted to it: producing cultivars of wheat that have semi-dwarf stems but long coleoptiles reduces the risk of poor establishment in these circumstances (Rebetzke *et al*., 2007).

PERSPCTIVES OF AGRONOMISTS, BREEDERS AND CROP PHYSIOLOGISTS

Wath then are the avenues open to use for using a limiting supply of water most effectively. Assuming that weeds, diseases and so on are under control? It is clear to agronomisrs, plant breeders and crop physiologists that matching a crop's physiology to its environment is the most important determinate of a well-managed crops water enconomy, the keystone of 'drought resistance'. In Mediterranean environment for example, getting the timing of flowering of crops right is especially critical-early enough to avoid the worst of the heat and large evaporative demands of late spring and summer. Yet late enough to avoid major risk of forst damage at flowering (Richards, 1991). In well-developed agricultural regions, that timing probably now as good as it can get. Given that optimal time is necessarily an avrage. For, depending on the pattern of rainfall during the growing season. Earlier flowering crops may do better in one season and later flowering onse may do better in another.

Working backwards from this optimal range of flowering time of annual crops. We have the question of what is the optimal trajectory of vegetative development in relation to making best use of a limiting water supply (Richards *et al*., 2002). In many instances the longer the vegetative span of the crop the better. At least in dry-land agriculture. If it means that evaporative losses from the soil are reduced and that there is better seed set at flowering, owing to there being more biomass then (Fischer, 1979). Fischer, much of that increased biomass might be available for remobilization and transfer to the developing grain, often an important contributor to water-limited yield (Blum, 1998).

There has of course been an immense amount of research concemed with how crops behave during a complete growing season in relation to getting the best out of a limiting supply of water. These include events of agronomic importance at sowing, establishment, tillering or branch growth, flowering and grain filling, or physiological or biochemical, processes such as those influencing the exchange of carbon dioxide for water vapour, or the partitioning of assimilate around the plant, or the processes that induce sterillety or maintain floral fertility during water stress at sensitive stages of floral development. Perhaps the most important practical knowledge to come out of all this research is the realization that the ecophysiological limits of crop yield in relation to water supply give a limit of about 20-22 kg of grain per millimeter of water transpired. At last with current cultivars and practices and averaged over a whole season (Passioura, 2006). This approximate limit has been well studied in temperate cereals: for example, Sadras and Angus (2006) have analysed several hundred experiments on wheat crops in four mega environments-south-eastem Australia, the North American grat plains, the China loess plateau and the Mediterranean basin and found no notable exceptions. This limit seems to apply to C_4 crops as well. Despite their transpiration efficiencies being famously much larger then those of C_3 plants, for they are generally grown in hotter climates with larger evaporative demands (Fischer and Turner, 1978). Oilseeds and leguminous crops have lower limits because of the greater energy content of the grain.

This realization of a practical limit has been an inspiration to many farmers because they treat it as a benchmark that helps increase the acuteness of their observations. If their own crops fall well below that benchmark they start searching for explanations why, which could. For example, be hitherto undetected problems with root growth, whether disease or chemical or physical constraints in the subsoil. or inadequate fertilizer practices (Passioura, 2006).

PERSPECTIVES OF PLANT PHYSIOLOGISTS, BIOCHEMISTS AND MOLECULAR BIOLOGISTS

Laboratory s typically work at short time scales (Table 1), the events that interest them are fast, ranging from nanoseconds for the fluorescence for light captured by chloroplasts, through minutes for the stomatal control that so influences that exchange of carbon dioxide for

water vapour by the leaves, to hours or days for the partitioning of assimilate that influences how plants balance. For example, the relative activity of their roots and shoot or the filling of grain. Chaves *et al.* (2003) have provided a wonderfully comprehensive review of much of this laboratory research that deals with processes that underline crop production.

Now while these fast processes form the basis for the slower processes whose connection with crop yield is reasonably clear, relating them directly to yield is difficult.

How difficult this is is not well appreciated by many laboratory scientists. For example, there are 2800 patents and patent application that are returned by searching for [('drought near/2 tolerance' or ' drought near/2 resistance') and 'plant breeding'] in CAMBIA, S BiOS patent database at http://www.PatentLens.net (2005), which includes primarily the US and Patent Cooperation Treaty (PCT) patent documents. Randomly exploring this collection gives the impression that a large proportion is concerned with metabolic or stress-induced genes having doubtful functional significance at the level of field-grown crop whose production is limited by water. Few provide evidence of performance in the filed or even try to articulate any connection with performance in the field.

One area that has attracted much attention is desiccation tolerance, the ability of plants to survive severe water deficits (Table 1). Work with transgenics involving the CBF/DREB transcription factors is proceeding apace, is coverd by 300 patents that also refer to drought tolerance and is intriguing in that with certain constructs, trans formed plants seem to be able to survive severe drying of the medium they are growing in. However, survival dose not mean production. And even if substantial improvement in survival could be made, it is likely to have little effect in the field, except perhaps for perennial pasture plants. Droughts that are severe enough to kill crop plants are rare.

The value of the huge research effort represented by 2800 patents and patent application is something we should ponder seriously. Overall the cost of establishing and maintaining such a large number of patents is likely to have been about 150 million US dollars paid to government patent offices and attorneys (the later being most of the cost). So far the returns seem to have been negligible. There may be a better way of spending this money if we are seriously interested in producing agricultural plants that perform better in the field during drought. The most notable of these patents that do have clear implications for performance in the field are typically associated with major companies such as Monsanto (Heard *et al.*, 2005) that are able to put large integrated teams, from molecular biologists to agronomists. Onto the problem.

Table 1 outlines how the time scales of phenomena that interest us rang from hours to a few years, a spread of more than three orders of magnitude. How can we best connect these phenomena? At the extremes of this range, how can we identify processes that take place in hours yet have substantial effects on grain yield that is the culmination of several months growth?

The connections can be subtle (Lafitte, 2005) and many be quite unrelated to plant water relations. Take the example of the influence of coleoptile length on the establishment of deeply sown cereal crops outlined above at the end of the section on Drought in relation to farm management. No laboratory scientist would become aware of the importance of coleoptile length without first being appraised of the operational problem in the filed. Yet it is a trait that could markedly improve crop yields when sowing is hampered by early drought.

Effective scaling up requires dialogue across scales Further, the dialogue generally needs to proceed by steps rather than leaps. There has to be enough commonality of language between a pair of practitioners. And a willingness to develop a reciprocal understanding of each others terms and working principles, for dialogue actually to take place (Passioura, 1979). For example, a farmer or an agronomist has no hope of usefully debating, in the way that a plant physiologist can, a molecular biologist's claim to have discovered a gene for drought tolerance. A plant physiologist would want to see data on the water relation of plants transformed with the putative gene-at the very least, the ability of the transformants to produce dray matter when given a fixed and limiting and measured supply of water. It is remarkable that to date few papers on such transformants provide elementary data on plant water relation despite some 2700 patents involving transformants that claim some relevance in this area. This is testament to a serious lack of dialogue, a lack that this meeting should help overcome.

This is not to argue that processes with time scales of hours or even days have no practical significance in farmers fields. Some crucially important processes occur this fast. Most notably those involved in the effects of water deficits (Saini and Westgate, 2000; Bennett *et al.*, 2005; Habben, 2005) or of frost on floral fertility. Indeed, a most exciting possibility with the CBF transcription factors is thir ability to improve frost tolerance (Miller *et al.*, 2006). Gerater tolerance of forest at fowring would enable breeders of crops with a winter-spring growing season to aim for earlier flowering, which would then give the crops a longer period of grain-filling in mild condition before the heat and aridity of late spring and summer thereby avoiding some of effects of the late drought. Remarkably though this connection between cold tolerance seems yet to be made by those transforming plants with CBF/DREB.

CONCLUSION

Drought has a wide rang of often quite disparate meanings. Even in the world of agricultural and plant science operational definitions vary greatly. Mostly because of the time scales of the events being considered. Of these time scales, those at which farmers operate are the guiding focus of this meeting. Research that aims to improve water limited yields on farms must ultimately make sense on farms. For the many of us whose research takes place predominantly in laboratories and which deals with phenomena that take place in hours, or even days, the challenge is to articulate the connectins between what we are doing and what farmers do, or at the very least, what agronomists and plant breeders do. To articulate these connections requires some commonality of language, of the terms that we use and of the ideas that such terms represent. Often the articulation is best done in steps. For example, if drought resistance, as understood by molecular biologist or biochemist, dose not make much sense to a plant physiologist it wil have no chance at all of making sense at this meeting gives us a rare and important opportunity of making these connections.

REFERENCES

Araus, J.L., J.P. Ferrio, R. Buxo and J. Voltas, 2007. The historical perspective of dryland agriculture: Lessons learned from 10000 years of wheat cultivation. Journal of Experimental Botany, (In Press).

Bennet, J., J.X. Liu and X.M. Ji *et al*., 2005. Flowering-stage drought stress in rice: Peduncles. Interdrought Abstract at http://www.planstress.com/id2/.

Blum, A., 1998. Improving wheat grain filling under stress by stem reserve mobilization. Euphytica, 100: 77-83.

Chaves, M.M., J.P. Naroco and J.S. Pereira, 2003. understanding plant responses to drought-from genes to the whole plant. Funct. Plant Biol., 30: 239-264.

Fischer, R.A. and N.C. Turner, 1978. Plant productivity in the arid and semiarid zones. Ann. Rev. Plant Physiol., 29: 271-317.

Fischer, R.A., 1979. Growth and water limitation to drayland wheat yield in Australia: A physiological framework. J. Aust. Inst. Agric. Sci., 45: 83-94.

Grove, A.T. and O. Rackham, 2001. The nature of Mediterranean Europe. An ecological history. New Haven CT Yale University Press.

Habben, J., 2005. Improving drought tolerance in maize: An industry perspective. Interdrought Abstract at http://www.plantstress.com/id2/.

Heard, J., T.R. Adams, G. Anstrom, R. Bensen, D. Nelson D. Warner, O. Ratcliffe, R. Creelman and S. Dotson, 2005. Increasing yield stability of come under drought conditions: New insights from transgenic studies Interdrought Abstract at Http://www.PlantStress.com/id2/.

Hyes, M.J., 2006. What is drought? Drought indices. Http://www.drought.unl.edu/whatis/indices.htm.

Lafitte, H.R., 2005. Whole plant responses, Key processes and adaptation to drought stress: The case of rice. Interdrought Abstract at http://www.Plantstress.com/id2/.

Meinig, D.W., 1962. On the margins of the good earth. Chicago, Il: Rand McNally.

Miller, A.K., G. Galiba and J. Dubcovsky, 2006. A cluster of 11 CBF transcription factors is located at the frost tolerance locus fr-a(M)2 in triticum monococcum. Mol. Genet. Genomics, 275: 193-203.

Passioura, J.B., 1979. Accountability, Philosophy and plant Physiology. Search (Sydney), 10: 347-350.

Passioura, J.B., 2002. Environmental biology and crop improvement. Funct. Plant Biol., 29: 537-546.

Passioura, J.B., 2006. Increasing crop productivity when water is scarce-from breeding to field management. Agric. Water Manage., 80: 176-196.

Rebetzake, G.J., R.A. Richards, N.A. Fettell, M. Long, A.G. Condon, R.I. Forrester and T.L. Botwright, 2007. Genotypic increase in coleoptile length improves stand establishment. Vigour and grain yield of deep-sown wheat. Field Crops Res., 100: 10-23.

Richards, R.A., 1991. Crop mprovement for temperate Australia-future opportunities. Field Crops Res., 26: 141-169.

Richards, R.A., G.J. Rebetzk, A.G. Condon and van A.F. Herwaarden, 2002. Breeding opportunities for increasing the efficiency of water use and crop yield in temperate cereals. Crop Sci., 42: 111-121.

RockstrÖm, J. and M. Falkenmark, 2000. Semiarid crop production from a hydrological perspective: Gap between potential and actual yieleds. Crit. Rev. Plant Sci., 19: 319-346.

Sadras, V.O. and J.F. Angus, 2006. Benchmarking water-use efficiency of rainfed wheat in dry environments. Aust. J. Agric. Res., 57: 847-856.

Saini, H.S. and M.E. Westgate, 2000. Reproductive development in grain crops during drought. Adv. Agron., 68: 59-96.

Worster, D., 1979. Dust bowl: The Southern Plains in the 1930s, New York: Oxford University Press.