第1卷 第1期
1982年9月
大豆科学
SOYBEAN SCIENCE
Vol.1 No1
Sept,. 1982

几种大豆品种若干耗水特性和水分利用率的研究

[法] R. 布朗谢, N. 格尔菲, A. 沫利恩, J. 蒲耶奇及其合作者J. 劳任特, M. 赫尔南德兹, B. 杜波伊思

(中法合作 一九八一年)

摘 要

对于中法合作计划，在法国研究了关于大豆水分的三个问题。

一、田间定点测定结果表明，耗水量随植株及叶面积的增加而增加，因单位面积叶片数的增加而降低。在冠层形成期（七月中旬），四种类型品种的蒸腾量相同，以后，则因叶面积指数及品种类型本身所固有的特性而不同。

二、通过盆栽试验，观测了30个品种的耗水量、叶面积和气孔特性。

1． 气孔阻抗的变异较大，约为3—8秒/厘米（sec/cm），因品种而异；气孔的调解阻抗对于叶片温度具有明显的作用。

2． "省水"品种的蒸腾量低，CO_2 同化作用较低，"省水"品种主要是由于有较高的气孔阻抗。增加气孔阻抗可缓和蒸腾作用，但也缓解了光合作用，因此，通常不能通过增加气孔阻抗的途径提高水分利用率。在无气孔阻抗影响的情况下，干物质产量和耗水量呈线性关系；籽粒产量和耗水量、叶片增长量之间无线性关系。

三、在没灌水的田间条件下，种植了从中国收集的品种。许多中国品种在法国表现优良，特别是铁丰18尤为突出，但遗憾的是这一品种显得晚熟。

（何志宏摘译）

STUDIES ON SOME CHARACTERS OF WATER CONSUMPTION AND WATER USE EFFICIENCY ON SOME SOYBEAN VARIETIES

R. BLANCHET, N. GELFI, A. MERRIEN, J. PUECH

Cooperative Research Program between
People's Republic of China and France, 1981

The modest contribution of the Station d'Agronomie to this cooperative program was directed on 3 points concerning soybean water problems:

A-Maximum evapotranspiration of 4 soybean types, in lysimeters.

B-Observations on water consumption, leaf aera and stomatal behavior on 30 varieties in a pot experiment.

C-Production of 25 varieties in small plots in the field, without irrigation.

The technics concerning these 3 points being quite different, they will be briefly described for each of them, before the indication of the results.

A) Maximum evapotranspiration in lysimeters

These 4 lysimeters have 3 m^2 of aera and 1 m of depth and are dayly supplied in surface by water according to the consumption of the day before; furthermore, a water table is maintained constant at o, 90 m depth, and the water supply-or the drainage-by this way is also registered. They are disposed in open air an irrigated soybean field of 0.5 ha, variety Hodgson, 35 plants by m^2, planted on April 24, giving an homogeneous environment. The soil is a well structured loam, well fertilized.

Table 1 gives the main climatic parameters of this year.

The undetermined varieties compared (1 by lysimeter) have about the same earlyness, but differ in their sizes and leaf characters:

-Hodgson, well adaptated to these conditions

-Heinong 26: about the same size and leaf aera index (LAI)

-Jiling 14, smaller LAI and size

-Hefeng 23, shortest and smallest LAI, about 10 days earlier

As it was not possible to make samplings in lysimeters before the end of growth, the same varieties were also cropped in pots (see below, part B) and harvested on August 19, at the maximum leaf aera (begining of grain filling); their characters, comparable to those of lysimeters plants, are given on table 2. The water consumption increased there with the size and leaf aera of plants, but decreased by dm^2 of leaves: that is not surprising. But these plants were not in an agricultural canopy, and for this trait let us consider the results of lysimeters, given by figure 1 and table 3.

Averages for periods		Temperatures, °C		Hours of sun	Rainfall mm	Control of Evapotranspiration, mm(x)	Relative humidity of air, %	
		min.	max.				min	max
May	1—10	8,3	15,8	32	36.0	33.0	67	96
	11—20	9,4	18.3	66	3.5	37.8	54	94
	21—31	10,4	19.4	72	33.5	37,2	57	94
June	1—10	13,0	24,1	85	9.5	49,2	52	95
	11—70	14,0	26,7	131	0	59,5	39	94
	21—30	11,8	20,6	67	36.0	62.2	55.	92
July	1—10	13,8	25,1	80	30.0	61,3	58	97
	11—20	14,2	22.1	52	7.0	40,5	62	96
	21—31	13.8	23,5	94	21.0	53,0	57	96
August	1—10	17,1	26,1	53	12.0	42.8	63	98
	11—20	14,8	27,3	100	0	52,1	48	98
	21—31	12,7	26,8	109	36.0	73,0	40	98
Sept	1—10	14,5	25,2	66	5,0	38,2	56	98
	11—20	14,4	24,5	61	0	27.9	56	98
	21—30	11,8	20,3	49	18.5	30,9	62	97
Oct	1—10	12,1	21,3	51	13,0	26,5	61	98
	11—20	13,5	19,9	32	17.5	25.4	74	98
	21—31	7,2	14,3	41	43.0	22,0	66	98

(x)measured in lysimeters with Festuca Arundinacea cropped as a continuous canopy

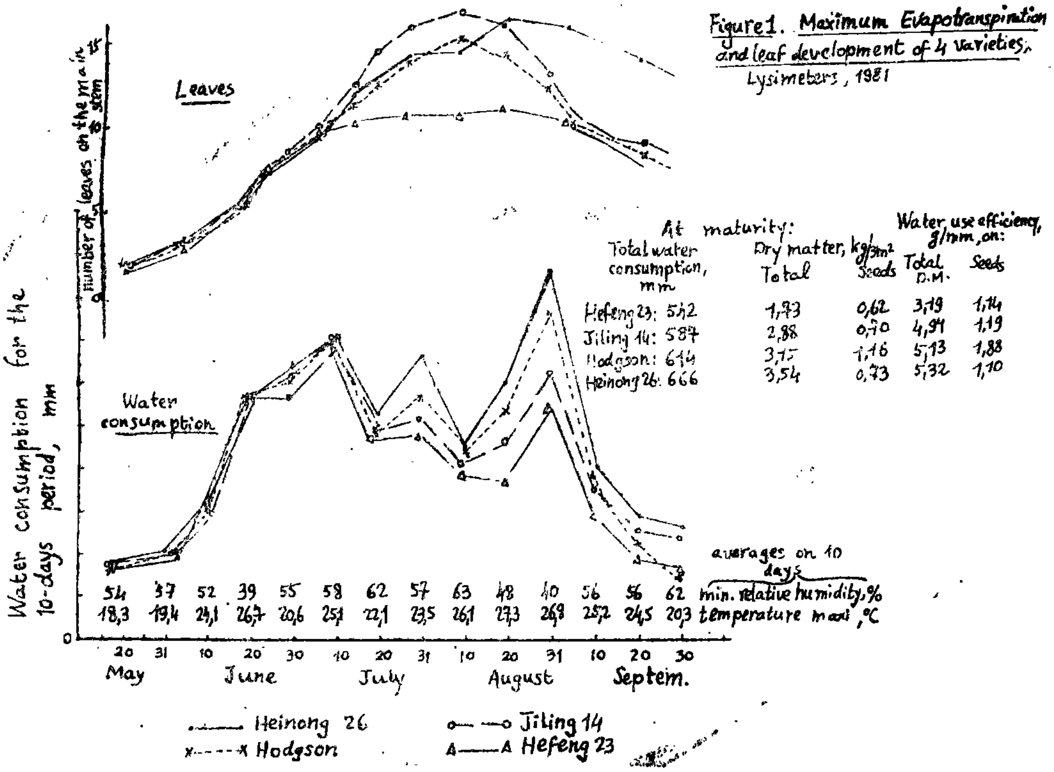
Table 1-Main climatic parameters

Variety	Height, cm	Green leaves area, dm²	Dry weight of green leaves, g	Total dry matter, g	Water consumption	
					Total, l/day	g/dm² leaves/day
Hefeng 23	75	9,5	3,8	17.6	0.16	17
Jiling 14	95	17,8	6.4	29.8	0.24	13,5
Hodgson	120	26,3	10,4	41,2	0.33	12
Heinong 26	110	24,5	10,6	44,2	0.36	15

Table 2- Main characters of plants at complete vegetative development; August 19.pots of 4 plants, results for 1 plant; lower leaves already dry in Hefeng 23.

Variety	Total water consumption mm	Height of plants, cm	Weight of dry matter, g/m² at maturity			
			Stems + petiolus	Leaflets	Seeds	Total D. M.
Hefeng 23	542	79	202	77	202	576
Jiling 14	587	94	483	132	233	965
Hodgson	614	100	393	152	385	1048
Heinong 26	666	106	633	180	244	1178

Table 3-Main characters of plants at maturity (lysimeters)



We can see that the 4 varieties had about the same evapotranspirations till mid-July, when they were developing their canopies. After, the water consumptions differed with LAI and probably propers characters, mainly in dry atmosphere (end of August) ; then the evapotranspiration increased markedly from Hefeng 23 to Jiling 14, Hodgson and Heinong 26, according to their vegetative development and giving total water consumptions ranging from 542 mm (Hefeng 23) to 666 mm (Heinong 26) . They were harvested at mid-October; despite the smaller transpiration of Hefeng 23 and Jiling 14, the best water use efficiency for total dry matter production ($\frac{\text{T. D, M.}}{\text{water consumption}}$)is given by Heinong 26 and Hodgson. The seed production is obviously a matter of adaptation to the environmental conditions. where Hodgson has the best place, but this experiment is interesting as an indication of the variability in water requirements and water use efficiencies among types in the field.

We can peculiarly observe on figure 1 that the greatest differencies of water consumption between varieties, when their foliage is well developed (mid-July) ,occur when the minimum relative humidity during the day is the lowest. The temperature seems to have a smaller effect. This behaviour leads to think that the extent of"doors of exit" of water (leaves and their stomata), on one hand, and the differences of water potential between leaf and atmosphere, on the other hand, play in such disparities of transpiration the main roles. The following pot experiment may precise these views.

B) Observations on water consumption, leaf aera and stomatal behavior in a pot experiment

This study was conducted in the natural environment, under a plastic shelter, with a controlled water supply ensuring maximum evapotranspiration. Each pot started in mid May with 5 plants; one plant was cut when

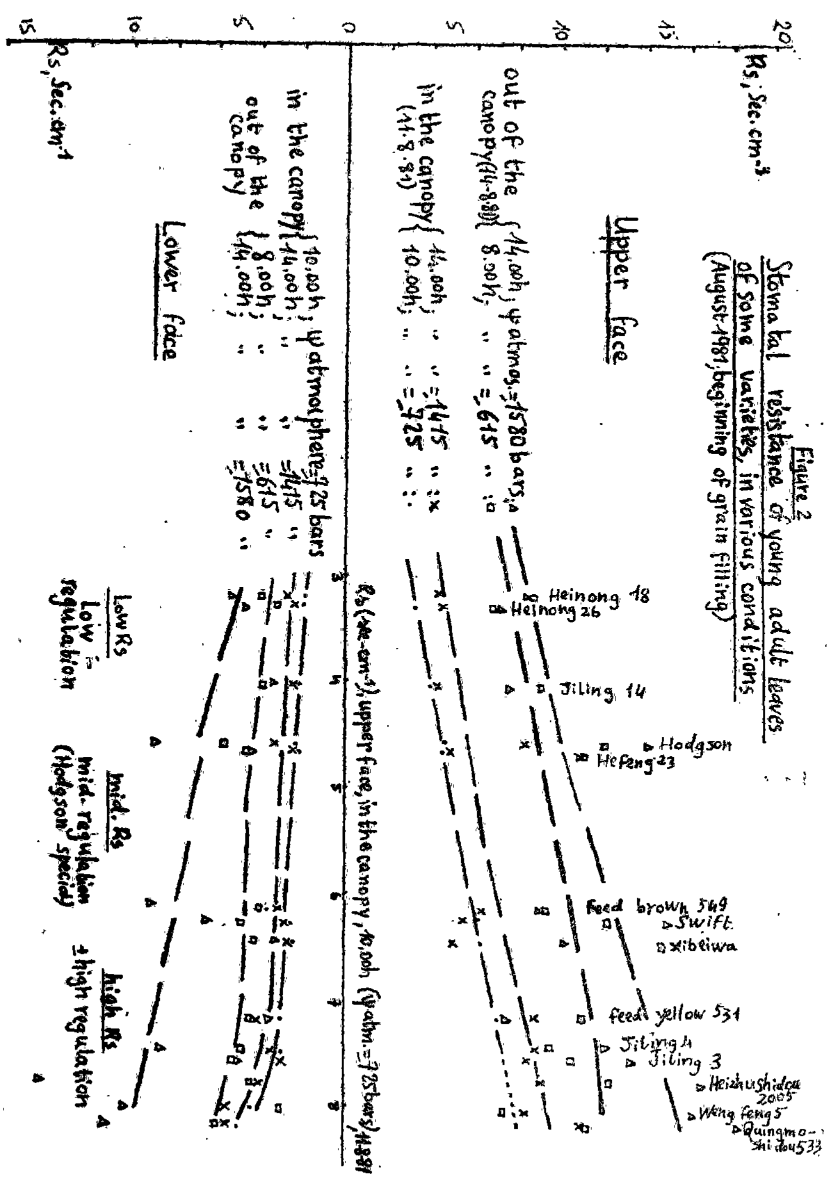


Figure 2 Stomatal resistance of young adult leaves of some varieties in various conditions (August 1981, beginning of grain filling)

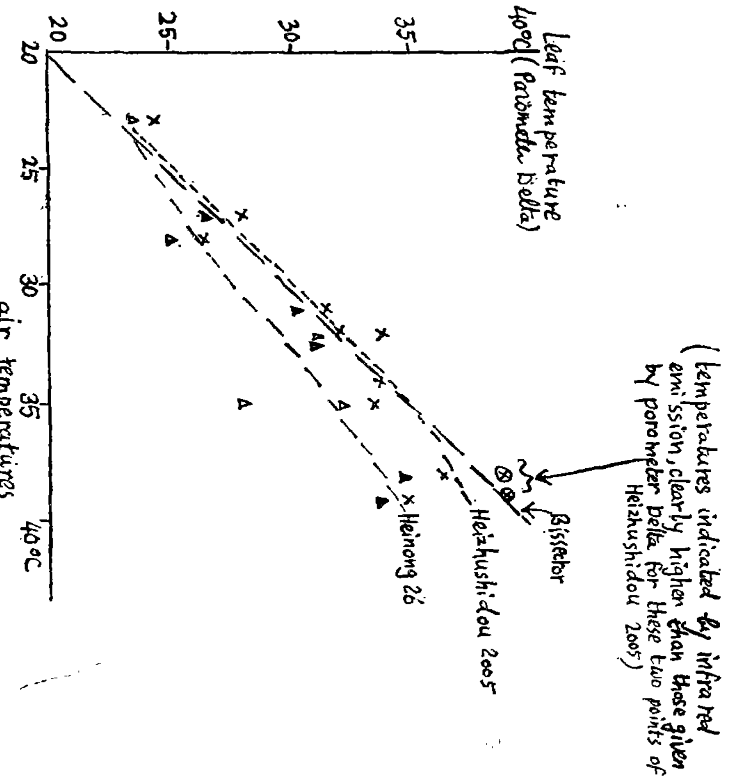


Figure 3 Temperatures of young adult leaves of Heinong 26 and Heizhushidou 2005, as functions of air temperatures. Pots out of the canopy, August 1984, stage grain filling.

the foliage was well developed (July 30) in order to estimate the leaf aera, and the other 4 plants were harvested at maturity (from the begining of September to early October). The dried leaves were carefully stored and weighted.

The pots were disposed in a canopy of about 18 plants per m², with addition of non-experimental border pots. For some detailed measures of stomatal resistance, the studied pots were extracted from the canopy in a sunny and warm day. These measures were made with a diffusion parameter (Delta, giving also the leaf temperature), on the upper and lower faces. In addition, some measures of leaf temperature were also made with an infrared emission pistol. Plastic impressions of the upper and lower epidemis were made; they are still in microscopic examination.

The varieties then studied are listed on table 4, in their order of reaching maturity. Because of the small number of available seeds, there were no replicates, and the results of production and water use efficiency are only indicative. Four replicates were only made on Heinong 26, Hefeng 23, Jiling 14, Swift and Hodgson.

B 1-**Stomatal behaviors**

The main results are summarized in figure 2: the more characteristic varieties studied are classified by increasing stomatal resistances of the upper face, measured in the canopy by a sunny and fine weather (27°C, 60% relative humidity, no wind). There was a large variation of Rs, from about 3 to 8 $sec.cm^{-1}$. Rs generally incresed in the afternoon, in a various extent depending on varieties.

Rs markedly increased in putting the plants out of the canopy, for comparable weather; that can be explained by greater interception of energy, and air circulation.

The resistances were lower on the lower face, according to the well known greater number of stomates on that face, and also increased with evaporative conditions.

In a general way, we found that varieties with low Rs (ex. Heinong 26) had a rather low regulation when evaporative demand increased, although varieties of higher Rs had a rather higher regulation. But there are exceptions, such as:

-Hodgson, with moderate Rs in good condition, has an important scale of regulation.

-Jiling 3 has a a higher"basal"Rs, but not a large regulation in those conditions.

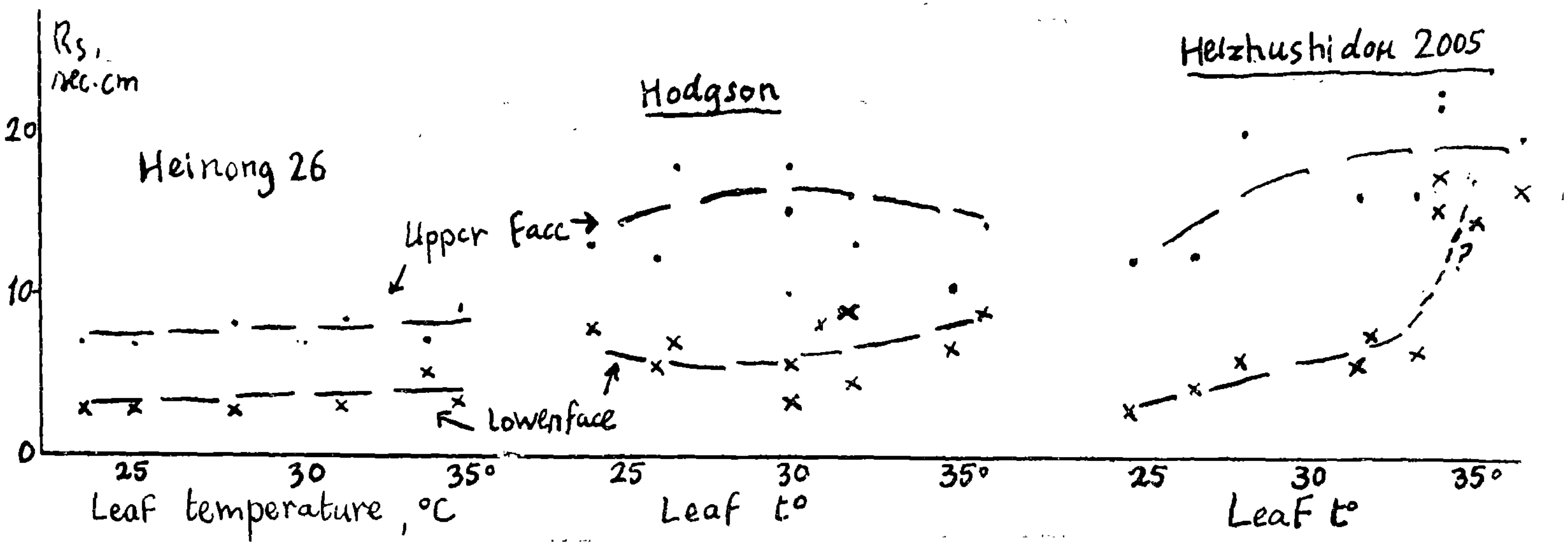
The highest resistances, both "basal" and "regulative", were found in Heizhushidou 2005, Weng Feng 5 and Quingmoshidou 533, yet vigorous and perhaps interesting for drought adaptation. Other varieties, such as Xibeiwa, had a good regulation on the upper face, but not at the lower, it seems. It was the contrary for Feed brown 549.

These stomatal regulations had a marked effect on leaf temperatures (figure 3). For instance, always Heinong 26 had a leaf temperature lower than atmosphere, while Heizhushidou 2005 had by warm weather 2 or 3 degrees more than Heinong 26. In rather drastic conditions (39°C in the atmosphere), we observed among varieties, by infrared emission, differences of near 10° C in leaf temperatures, the highest corresponding to highest Rs and conversely.

These types of behavior are summarized on figure 4, assuming that leaf temperature can be an indicator of the evaporative demand and of the plant reactions: Heinong 26 does not show a great stomatal regulation, and the contrary happens in Heizhushidou 2005, Hodgson being intermediate. But these results were obtained at the end of the development cycle, and are only indicative of ways of further research.

Figure 4.

3 types of stomatal resistances, varying or not with the leaf temperatures. Diffusion porometer Delta, pots out of the canopy, stage grain Filling, good luminosity – Provisional results.



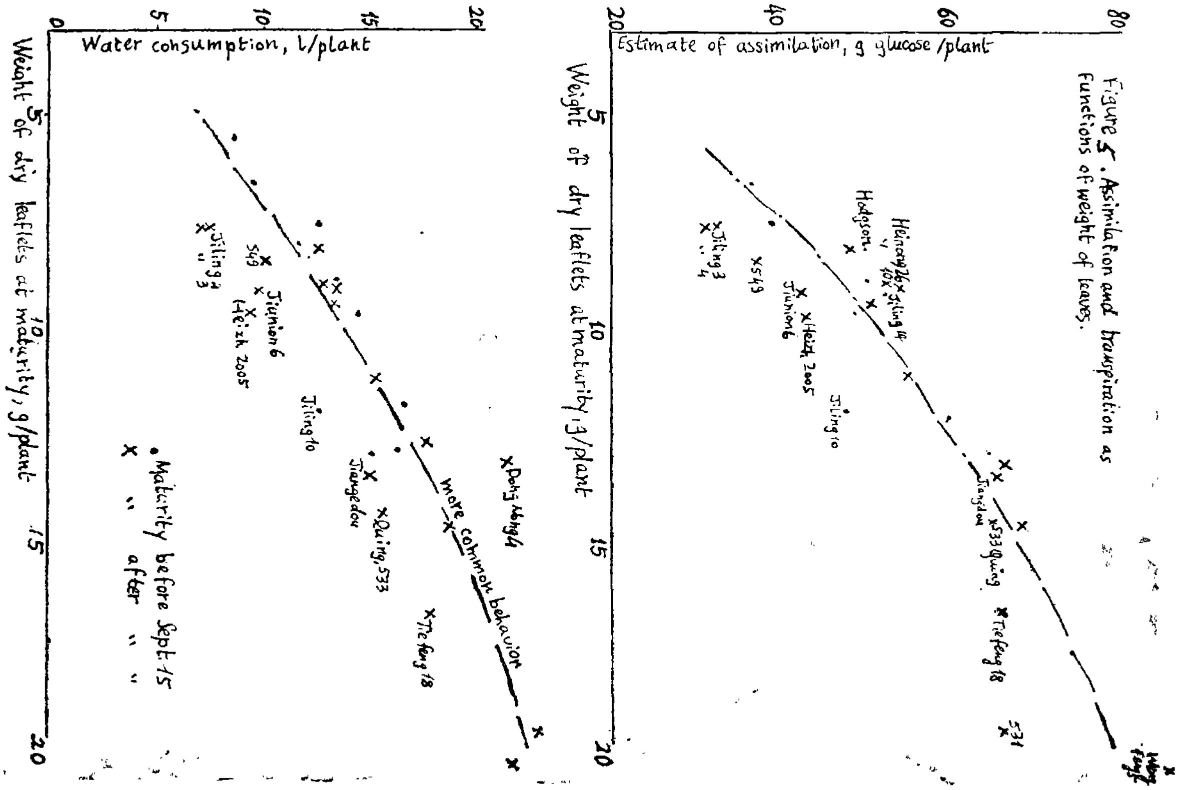


Figure 5. Assimilation and transpiration as functions of weight of leaves.

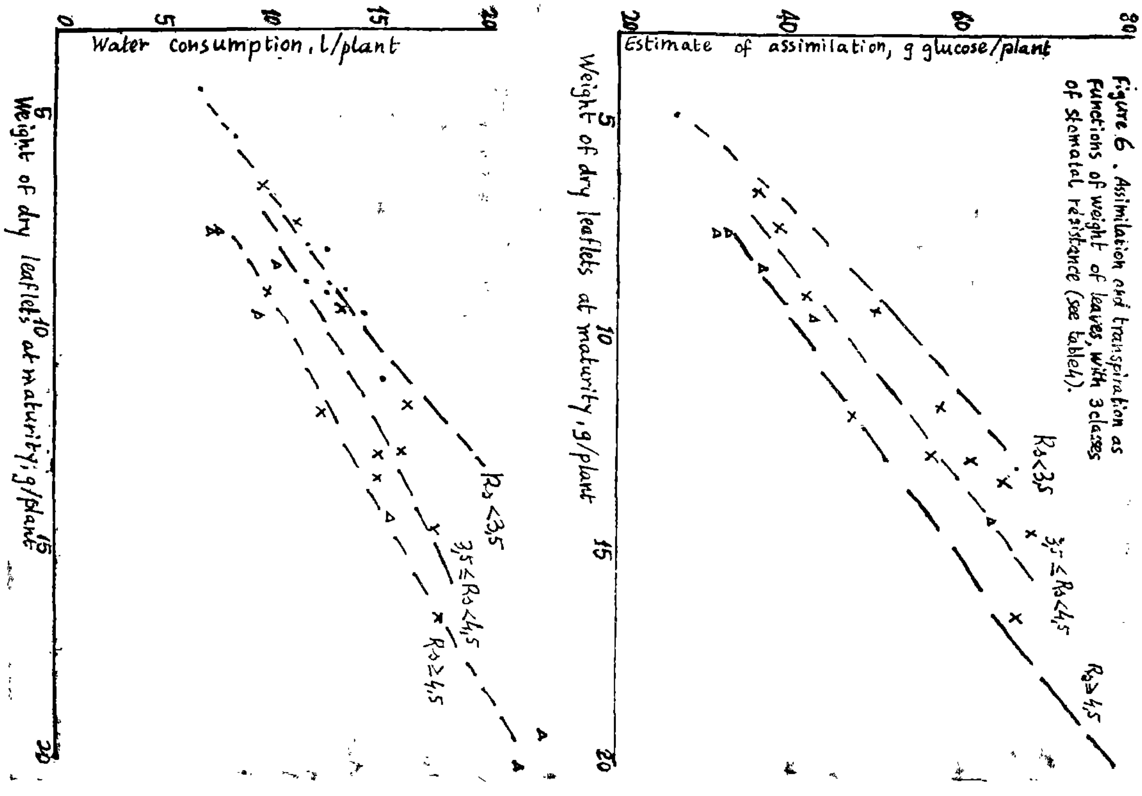


Figure 6. Assimilation and transpiration as functions of weight of leaves, with 3 classes of stomatal resistance (see table 4).

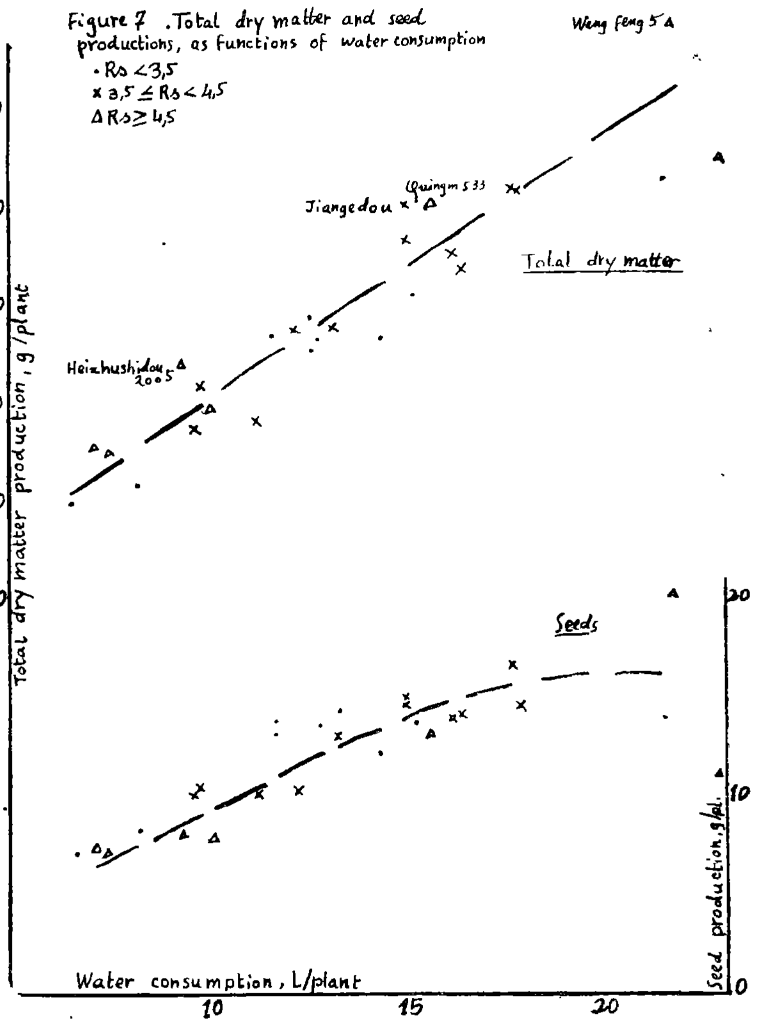


Figure 7. Total dry matter and seed productions, as functions of water consumption

B 2- **Water consumption, leaf characters and production**

As indicated by table 4, we observe a large variability in leaf areas, water consumptions, and productions. Let us note that, in this experiment, the leaf aera index was **in average** (all the varieties) of about 5, allowing a rather good penetration of light and circulation of air. Then, the varieties were not in their **own** environment, but in a common one, and that probably advantaged the most vigorous ones, which were not in a strong competition.

The weights of the dry leaflets at maturity seem to give a better indication of the foliage development than the leaf areas at a given date; we are used to consider this character when it is possible. Plotting the water consumptions as function of it, we can observe on figure 5:

–a general and less–than–proportional ralationship;

–some "water–saving" varieties, whose transpiration is inferior to the common behavior for the same weight of leaflets: Jiling 3, 4 and 10, Feed

549, Jiunion 6, Heizhushidou 2005, Jiangedou, Quingmoshidou 533, Tie Feng 18.

-a "wasting" variety: Dong Nong 4

-in those conditions, the earlyness had no great influence on that relationship: although the water-saving varieties are rather late, there is no general distinction between early and late on the basis of their foliage extent, and on the ratio water consumption/foliage extent.

Trying to appreciate the CO_2 assimilations of these foliages, we made an estimate derived from the works of PENNING DE VRIES, and taking in account the energy requirement of the synthesis of oil and proteins in seeds (the publication of our approach is in press in the review "Agronomie"). For that purpose and in a first approximation, we calculated this estimate of assimilation (glucose) by the sum:

Weight of stem+petiolus+leaflets+empty pods+2 [weight of seeds]

It is a very coarse estimate, but more accurate than the total dry matter. If we plot those values as function of the weight of leaflets (figure 5, above), we can see that the "water-savig" varieties also seem to have rather low assimilations by unit of leaflets, except Jiangedou and Quingmoshidou 533. Some performant varieties such as Heinong 26 and 10, Jiling 14, Hodgson, on the contrary, appear in a good position.

Then, it seems to appear a sort of linkage between transpiration and assimilation in the leaf activities, and we tried to see if it was related to stomatal resistances. For that, we took the averages of two faces Rs observed in good conditions of light and temperature (Table 4) and we made in them 3 classes. Figure 6 shows that water consumptions, plotted like above

varieties, classified in their order of reaching maturity		Stomatal resistance, Rs, (1) sec/cm	Results for 1 plant						
			Approxim. leaf area on July 30, dm² (2)	Dry weight of leaflets at maturity g	Total water consumption l	Dry matter (D.M.) production		Water use efficiency, g/l. on:	
						Total, g	Grain, g	Total D.M.	Grain
Hei Ho	3	3,1	12	5,50	8,26	21,7	8,17	2,63	0,99
Hefeng	23	3,3	17	4,88	6,73	19,7	7,09	2,95	1,06
Swift		4,1	20	6,6	9,73	27,0	10,0	2,80	1,04
Heinong	11	3,4	21	8,8	11,71	36,0	13,85	3,07	1,18
Jiling	15	3,6	17	7,45	11,28	28,8	10,0	2,55	0,89
Kexi	283	4,2	41	12,8	16.15	45,2	14,0	2,80	0,87
Jiling	10	3,55	35	11,9	12.27	37,4	10,1	3.05	0,82
Jiling	14	3,1	24	9,1	12,64	38,6	13,9	3,06	1,10
Hodgson		3,4	36	8,0	11.70	36,8	13.2	3,14	1,15
Xibeiwa		4,35	53	11,7	16,41	43,4	14,2	2,64	0,86
Jiunion	5	3,15	35	9,6	14,41	36,5	12,3	2,53	0,85

Dong Nong	1	3,6	33	12,9	14,95	46,6	14,9	3,12	1,0
Zhinuanong	2	2,9	33	11,1	15·19	40,9	13,9	2,69	0,92
Jiling	4	5,2	33	7,6	7,53	24,4	7,0	3,24	0,93
Heinong	16	4,0	26	9,4	13,57	37,6	13,0	2,83	0,98
Zhinuanong	3	3,9	44	14,6	17,67	51,4	16,9	2,91	0,96
Heinong	18	2,55	48	8,1	12,64	35,0	13,7	2,77	1,08
Jiling	3	5,1	19	7,6	7,23	25,4	7,3	3,51	1,01
Heinong	10	3,05	35	8,9	12,77	38,1	13,6	2,98	1,06
Feed brown	549	4,9	32	8,4	10,12	29,4	7,8	2,91	0,77
Jiunion	6	3,50	18	9,1	9,80	31,5	10,8	3,21	1,10
Dong Nong	4	3,3	25	13,1	21,52	52,5	14,0	2,44	0,65
Heizhushidou	2005	5,3	28	9,7	9,39	33,9	9,0	3,61	0,96
Jiangedou		4,45	30	13,4	15,00	50,3	15,0	3,35	1,00
Heinong	26	2,65	23	9,0	13,34	39,7	14,4	2,97	1,07
Tie Feng	18	3,65	32	16,6	17,78	51,6	14,7	2,90	0,83
Quingmoshidou	533	6,55	45	14,3	15,58	50,2	13,2	3,22	0·85
Feed Yellow	531	5,05	83	19,4	22,85	54,6	11,3	2,39	0,49
Weng Feng	5	6,1	30	20,3	21,65	68,5	20,4	3,16	,94

(1)Average of the two Faces, 11/8/81, 10 h a. m, 27°C,60% relative humidity, sunny weather

(2)Some late varieties, especially Jiangedou, Dong Nong 4, Tie Feng 18, Weng Feng 5,had not achieved their leaf development

Table 4—Main characters of the plants in pot experiment

as function of dry weight of leaflets, classify rather well according to Rs: the "water-saving" varieties mainly have a higher Rs. The estimates of CO_2 assimilation give a rather similar picture, but not so well differenciated by Rs than water consumptions. Then, here, increasing Rs seem to moderate transpiration (this is quite logical) , but also to moderate photosynthesis, so that the water use efficiency does not increase in a general way with Rs.

Coming back to a more usual character,if we plot the total dry matter productions as functions of water consumptions (figure 7) , we can see here a linear relation, without any effect of Rs. But we note the good behavior of Jiangedou and Quingmoshidou 533, and also Heizhushidou 2005 and Weng Feng 5, that we emphasized above.

Seed production does not give a linear relation with water consumption and foliage development; we already observed that in previous works, the equilibrium between vegetative and reproductive organs being a difficult question of both physiology and environment. We will not discuss here this point, because this experiment is not sufficiently precise. But we note the particular interest of varieties both "water-saving" and productive in seeds (Jiangedou...)

of course, this experiment is only a first view, and these results have to be precised and perhaps confirmed in more detailed and occurate studies. But the large variability of this plant material in its water relationships is very intererstíng, and we are grateful to our Chinese colleagues for providing us with it.

C) **Production of some varieties in small field plots, without irrigation**

These varieties, indicated on figure 8, were cropped in a loamy deep soil having about 250 mm of water available for crops, well fertilized, and inoculated by **Rhizobium japonicum**. Depending of available seeds, each variety was planted early May on 1 to 3 lines 5 m long, in an environment

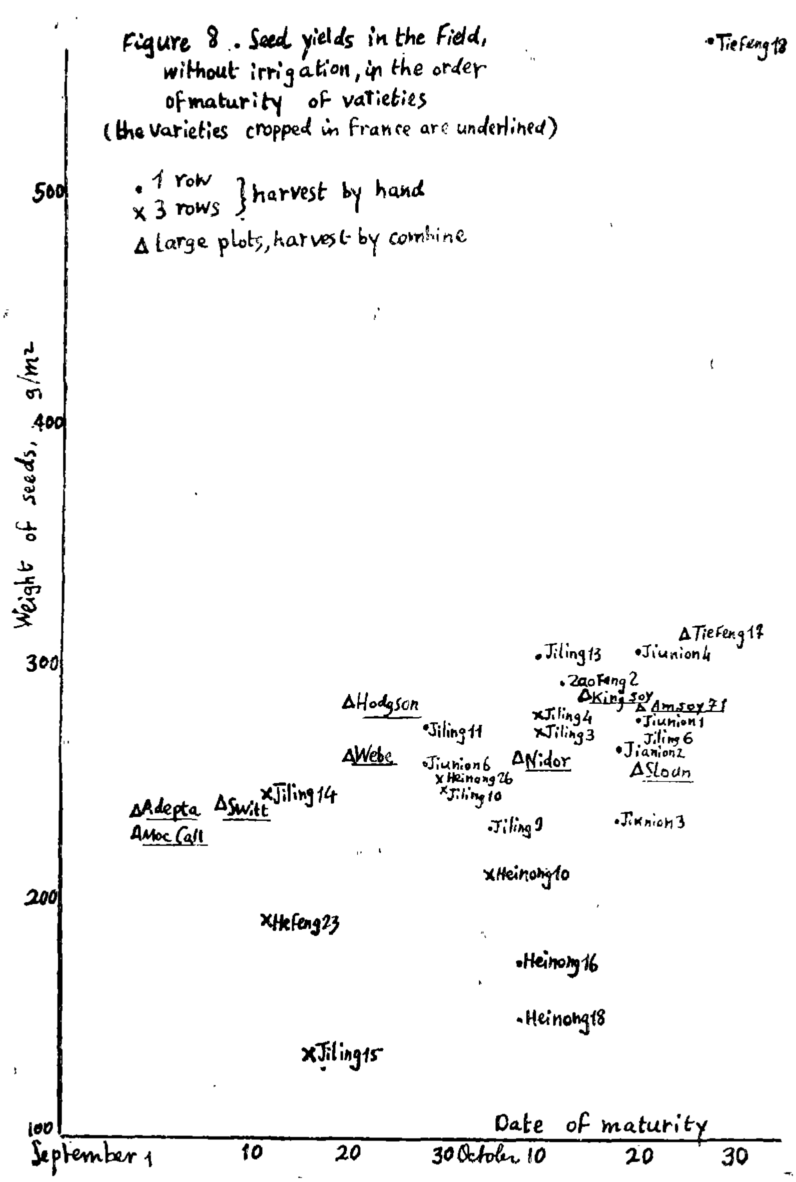
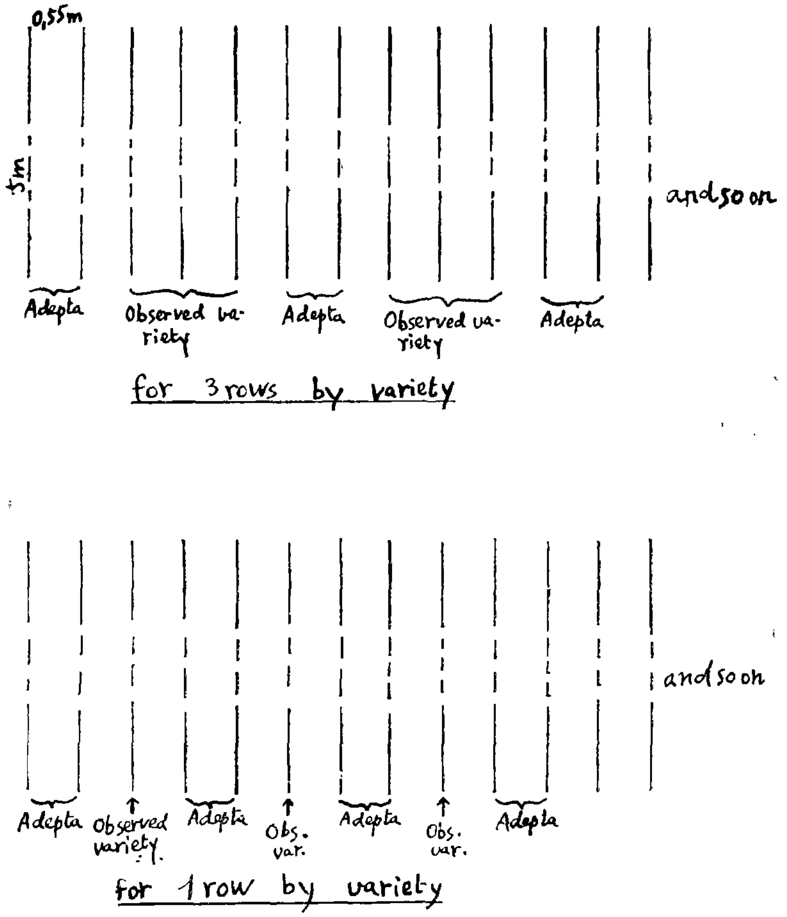


Figure 9. Schematic disposition of the small plots in the field



of the early variety Adepta, 35 plants/m² (figure 9). Such small and variable areas, with non-uniform competitions, and lack of replicates, of course do not permit correct comparisons, and the results are **only indicative** of tendancies of behaviors.

Current varieties cropped in France were also observed in the same field and in the same conditions, in larger plots.

Although August was dry, the plants did not suffer too much, and we only noted marked wiltings on Jiling 15. On the contrary, Jiling 3, Jiling 10 and Tie Feng 18 marked no great signs of suffering.

Harvest was made as maturity occured, from the end of August to the end of October, by hand for the small plots, and by a combine for the larger plots. We must note that the late varieties in small plots, especially those in one row, were advantaged by the early maturity of their environment of Adepta, which matured at the end of August. From that time, to their own maturity, the isolated rows of late varieties had no competition between rows, in the air and in their root system.

Figure 8 indicates the rerults. We can see that numerous Chinese varieties had a good behavior, for instance Jiling 3, 4, 10, 11, 13, 14; Jiunion 1, 4, 6; Heinong 26; Zao Feng 2; Tie Feng 17 and mainly Tie Feng 18 which reached a very high yield. Although we know the very good reputation of Tie Feng 18, its so high performance here is rather surprising; we must remember that it had no competition after Adepta maturity, but certainly this variety is of the greatest interest (unfortunately it is late for our regions).

Of course, the yields in such a moderate water deficit result both of the characters of the aerial parts (transpiration, fructification), and of those of the root system. But we can note that all the varieties emphasized above as "water-saving" (figure 5), when present here, have good results: Jiling 3, 4 and 10; Jiunion 6; Tie Feng 18.

All these results are then coherent and encouraging.

CONCLUSIONS

From these various studies it appears a large variability in the plant ability of an efficient water use for production, and probably of their aptitude to pick it in the soil by their roots. The processes of saving water are only foreseen, and there is a great need to understand them. We will try to do that next year, and in the future. This material is convenient for that purpose; perhaps could we wish earlier types adaptated to drought, the most adaptated of the present collection being rather late (figure 5): no early type appears "water-saving". Do they exist? Do any earlier types jointly have rather low transpiration, moderate foliage, high photosynthesis and productivity, as seem to have Jiangedou, Quingmoshidou 533..., in a later way?

We leave our Chinese colleagues judges of this question, and of course of the present results.

R. BLANCHET, N. GELFI, A. MERRIEN, J. PUECH
with the cooperation of J. LAURENT,
M. HERNANDEZ and B. DUBOIS

November 1981