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RAIN-FED CROP PRODUCTION SYSTEMS OF UPLAND BALOCHISTAN
2. BARLEY (HORDEUM VULGARE)

by

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Short title: Rain-fed barley in upland Balochistan

Rain-fed crop production systems of upland Balochistan

2. Barley (*Hordeum vulgare*).

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SUMMARY

This is the second in a series evaluating the potential for improved crop productivity in upland Balochistan. The growth and yield of a number of Syrian barley land-races and varieties were compared with that of the local land-race on farmers' fields under dryland conditions from 1985 to 1988.

Rainfall during crop growth varied from 32 to 220 mm, and grain yields varied from 10 to 1250 kg ha^{-1}, averaging 350 kg ha^{-1}. The Syrian land-races generally produced higher grain yields than the local, but with the exception of Arabi abiad produced lower straw yields. Genotype-environment analyses indicated that Arabi abiad could be expected to produce more grain, similar amounts of straw and higher gross benefits than the local in all environments except the most severe in which crop failure was assured.

Application of nitrogen and phosphate fertiliser increased yields in almost all trials, but the increases were sufficient to pay for the fertiliser in only one trial.

The water use efficiency of the local barley land-race was 11.2 kg ha^{-1} mm^{-1}, and when adjusted for differences in water availability the barley yields were 35% higher than for dryland wheat, overall.

Seed and straw prices varied with season and availability, and net benefits varied from -86 R ha^{-1} in the drought season of 1987/88 to 1269 R ha^{-1} in the "wet" season of 1986/87, averaging 555 R ha^{-1}, 80% higher than for wheat. Net benefits and returns to labour were 24% and 16% higher for the Arabi abiad land-race than for the local land-race.

The results suggest: (a) Arabi abiad would be a valuable introduction to upland Balochistan; and (b) some increase in barley production at the expense of wheat could considerably improve farmer circumstances.

INTRODUCTION

The major dryland agricultural activity in upland Balochistan is small ruminant production with range-land grazing providing most of the animal feed (Buzdar *et al.*, 1989a). Barley is grown under dryland conditions as an animal feed, but the principal cereal grown is wheat (Buzdar *et al.*, 1989b), in contrast to areas with similar climates in the Middle East and North Africa (Ceccarelli, Grando & Van Leur, 1987). The farmers' yield expectations are low, ranging from 0 to 300 kg ha^{-1} on rain-fed land, and from 100 to 600 kg ha^{-1} on land that receives occasional irrigations from ephemeral streams (Rees et al., 1988). There is a pressing need for policies and farming practices that reduce the pressure of livestock production on range-lands and marginal crop-lands not only in Balochistan but also throughout West Asia and North Africa (Somel, 1988). Improved and increased barley production is one way in which this might be achieved, particularly in upland Balochistan. The purpose of this paper is to evaluate the prospects of increased productivity in upland Balochistan through the introduction of exotic barley germplasm, and to compare the potential for barley production with that for wheat reported in Part 1 (Rees et al., 19XX).

MATERIALS AND METHODS

The trials were carried out on farmers' fields at a number of sites in upland Balochistan from 1985/86 to 1987/88. Trial locations, descriptions of the soils, measurement of temperature, rainfall, soil water at planting and trial management are described in Part 1 (Rees et al., 19XX). Five drought and cold resistant barley land-races and lines from Syria, supplied by ICARDA, were tested against the local Balochistan land-race with and without fertiliser. Row spacing was 40 cm and seed-rate was 90 kg ha^{-1}, following local practise. Sixty kg ha^{-1} phosphate as 46% triple super-phosphate and 10 kg ha^{-1} N as 26% ammonium nitrate were mixed with the seed just prior to planting for those treatments receiving fertiliser. An additional 30 kg ha^{-1} N was broadcast at tillering. The trials were planted as was randomized complete blocks with three replicates of each treatment. In 1986/87, the trials in two areas (Dasht, Kovak) were divided into two and one half of each plot was cut by hand to a height of 5-10 cm above the ground for an estimate of green herbage production. Data from the cut and un-cut portions were subsequently analyzed as separate trials. Herbage production (above-ground dry weight at flowering) was estimated from two 1-meter samples of row per plot; final yields of mature crop were estimated by harvesting the entire centre two rows of each plot. The crude protein content of herbage, seed and straw samples were determined following the procedures of AOAC (1984).

The "farm-gate" prices of barley seed and straw increased with time, particularly in the drought year of 1987/88: seed prices were 1.5, 1.75 and 4.0 R kg^{-1} and straw prices were 0.5, 0.6 and 1.0 R kg^{-1} in 1985/86, 1986/87 and 1987/88 respectively. (In 1988 18 R = 1 US $). Details of other costs used for partial budgeting are given in Part 1 (Rees *et al*., 19XX).

RESULTS

The weather and crop growth

Soil water at planting, rainfall during crop growth and trial mean yields are presented in Table 1. The soil water at planting was somewhat higher in the barley trials than the wheat trials in 1985/86 (Part 1, Rees et al., 19XX). As discussed in Part 1, 1985/86 was characterized by crop emergence at the end of January with little exposure to cold stress and low rainfall during crop growth, resulting in considerable water stress and poor final yields. The landraces Arabi abiad and Arabi aswad gave higher yields than the local in two of the four trials, but the differences between varieties were not statistically significant in any trial. Responses to fertiliser were small and also not statistically significant.

In 1986/87 the crops were planted in September/October and experienced considerable cold stress during winter, but only moderate levels of water stress. None of the barley varieties showed serious signs of cold damage. Grain yields were much higher, ranging from 320 to 1250 kg ha^{-1}. The exotic varieties gave higher grain yields than the local in all but one trial, but, with the exception of Arabi abiad, lower straw yields. Averaged over all varieties and trials fertiliser increased grain yields from 700 to 820 kg ha^{-1}, and straw yields from 1150 to 1400 kg ha^{-1}, but the increases in gross benefit, ranging from 170 to 620 R ha^{-1}, exceeded the cost of the fertiliser (516 R ha^{-1}) in only one case.

In 1987/88 late rains delayed emergence until late February, resulting in a shortened growing season, and rainfall was low, resulting in severe water stress and crop failure, except in the two trials that received pre-planting irrigation. Responses to fertiliser in these conditions were small, as were differences between varieties; but as noted in the earlier trials, the Syrian germplasm tended to give slightly higher grain yields and, with the exception of Arabi abiad, slightly lower straw yields than the Balochistan local.

Crop cutting for green herbage.

Table 2 presents the results of crop cutting for herbage in December for the Kovak and Dasht trials. Herbage yields were higher at Dasht, where soil water at planting was high, than at Kovak, where soil water at planting was low. Straw and grain yields were reduced by cutting for herbage at the tillering stage by an average of 11 and 14% respectively, resulting in 19% and 5% decreases in gross benefit at Kovak and Dasht, respectively.

Comparison of local and exotic germplasm

The results of the three years' trials are summarized in Table 3. Averaged over all trials and years, Arabi abiad produced significantly more herbage yield than the Balochistan land-race. All the Syrian germplasm produced significantly less straw than the local, with the exception of Arabi abiad; and all the Syrian germplasm produced more grain than the local, though this was statistically significant only for Arabi abiad and Tadmor. This reduction in straw, but increase in grain, resulted in only small differences between the Syrian material and the local in gross benefit, except in the case of Arabi abiad, which gave a 10% increase in gross benefit, though this was not statistically significant. Fertiliser gave significant increases in straw and grain yields, but as discussed above, the resultant increases in gross benefit were not sufficient to meet the cost of the fertiliser applied. Accordingly, subsequent analyses were restricted to treatments without fertiliser.

Table 4 summarizes genotype-environment analyses in which linear regressions between yield for each variety and the site mean yield were calculated, and the regressions for each of the Syrian varieties compared with that for the control. The slopes of the regressions for grain yield of the Syrian varieties were greater than that of the local in all cases, whilst those for straw yield were less than that of the local in all cases except Arabi abiad. For gross benefit, Arabi abiad resulted in a higher slope, and a lower y-axis intercept, than the local, indicating that, as shown in Figure 1, in all circumstances except those in which gross benefits are so low as to represent crop failure, Arabi abiad can be expected to produce a higher gross benefit than the local.

Figure 2 shows a close linear correlation between total above-ground dry weight at maturity and a "water availability index" calculated as the sum of soil water at planting plus rainfall during crop growth. The slope of the line, 11.2 kg ha^{-1} mm^{-1}, represents the change in dry weight per unit of water, or the water use efficiency of the crop in upland Balochistan conditions. This close correlation between the "water availability index" and crop growth indicates that this index could be used in place of site mean yield as a measure of environmental conditions in a genotype-environment analysis. Table 5 summarizes the results of such analyses. As seen in the previous analyses, the slopes and x-axis intercepts indicate that over most of the range of "water availabilities" the Syrian varieties produced more grain and less straw (with the exception of Arabi abiad) than the local, but the only difference that was statistically significant was that for grain between Arabi abiad and the local.

Partial budgets for the local and Arabi abiad land-races without fertiliser are summarized in Table 6. The higher productivity of Arabi abiad resulted in slightly increased harvesting and threshing costs and labour requirements, but net benefits were still increased compared to the local. Net benefits and returns to labour were low in the "normal" rainfall year of 1985/86 and negative in the drought year of 1987/88, but reasonably high in the "good" rainfall year of 1986/87. Overall Arabi abiad without fertiliser gave 24% higher net benefits and 16% higher returns to labor than the local land-race without fertiliser.

Table 7 compares crude protein contents from 1988 dryland barley crops without fertiliser application with those of the local wheat (the straw of which represents the main crop product used as feed for sheep and goats in Balochistan). At all growth stages the protein contents of the barleys were greater than that of the wheat, with some indication that Arabi abiad seed had a higher protein content than the local barley, but this needs to be confirmed in more extensive testing.

DISCUSSION

Barley grain yields observed in these trials averaged only 350 kg ha^{-1} which is low compared to the figure of 1 t ha^{-1} reported for the Middle East and North Africa under rain-fed conditions (Ceccarelli, Grando & Van Leur, 1987), and also low compared to the Pakistan average yield quoted by Jalil & Ghani (1982) of 740 kg ha^{-1}, but are in agreement with farmers' yield expectations (Rees et al., 1988). Net benefits and returns to labor were correspondingly low, but almost double those for dryland wheat (Part 1, Rees et al., 19XX). This is partly due to the government policy of a fixed price for wheat seed, and to a slightly higher water availability in the areas selected for the barley trials, but mainly due to the greater drought tolerance of barley. The relations between yield and the water availability index provide a convenient way of comparing wheat and barley growth in dryland conditions in upland Balochistan: the relation between above-ground total dry weight at maturity (y) and the water availability index for wheat without fertiliser was $y = 8.7(x - 126)$ (Part 1, Rees et al., 19XX), compared to $y = 11.1(x - 121)$ for the local barley without fertiliser. The overall average water availability index was 217 mm, which results in yields of 792 and 1066 kg ha^{-1} for wheat and barley, respectively, a 35% higher yield for barley than for wheat. There thus seems to be little biological or economic reason for the farmers of upland Balochistan to grow wheat rather than barley, suggesting that the principal reason is the farmers' concern to ensure a supply of wheat for their families, as reported by Nagy et al. (1988).

The Syrian land-races and varieties generally produced more grain and less straw than the Balochistan land-race, with the exception of Arabi abiad, which produced more grain and similar amounts of straw. As a result only Arabi abiad resulted in higher net benefits and returns to labour than the local. Arabi abiad has also been reported to out-yield Arabi aswad in Syria (Ceccarelli, Grando & Van Leur, 1987; Yau, 1987; Ceccarelli & Grando, 1989).

Application of nitrogen and phosphate fertilisers increased yields by 16% overall, but the increase in yield was sufficient to pay for the fertiliser in only one trial. This result is similar to that observed for wheat (Part 1, Rees et al., 19XX).

Crop cutting or grazing at the tillering stage is a common practise in the Middle East and North Africa (Anderson, 1985), as well as in upland Balochistan if conditions are favorable. The data presented here suggest that this practise was of little economic benefit even in the good rainfall year of 1986/87. This is in broad agreement with the results of Anderson (1985) and Yau & Mekni (1987), who reported that green stage grazing had little effect on final yields in "wet" years (greater than 300 mm), but considerably reduced yields in "dry" years (260 mm or less).

The practise of cutting crops for hay at flowering for animal feed during winter is carried out by 28% of dryland farmers in upland Balochistan (Nagy *et al.*, 1988) and may be worth considering as a possible intervention; the crude protein contents are high enough to make this a valuable animal feed, the awns of both the local and the Syrian land-races are not rough enough to reduce palatability, and in nearly all the trials total dry weight at flowering was higher than at harvest as a result of the cessation of the rains at about the same time as flowering (a rainfall pattern typical of the area and most of the Mediterranean region as well). This possibility of hay production needs to be tested against the alternative of preparing feed rations from the straw and seed. Capper *et al.* (1986) reported a crude protein content of Arabi abiad straw of 3.6%, similar to that reported here, and found that voluntary intake of this straw by Awassi sheep was sufficient to meet estimated maintenance requirements in 1981/82 but not quite in 1982/83. They attributed this relatively high nutritive value for a cereal straw to the high proportion of leaf to stem for this land-race. Experience of the Balochistan Livestock Department suggests that rations formulated from the local barley land-race of 50% seed, 50% straw should be sufficient for fattening Balochi sheep for meat and for maintaining live-weights and fertility of ewes over winter (L. Meyer, personal communication, 1989). There is thus considerable potential for improving animal productivity through strategic feed supplementation, using either barley hay or a mixture of seed and straw.

The results presented here demonstrate a reasonable potential for increasing productivity by the introduction of the Arabi abiad land-race, and also suggest that there is a strong case for encouraging some change from wheat production to barley production. Using barley for increased animal production would inevitably increase risks compared to selling excess in the market, and so major changes of this nature would require better access to livestock markets, and would also be encouraged by improved flock management, including prophylactic animal health care and better feeding regimes (ICARDA, 1988). The identification of a higher-yielding barley land-race is a promising beginning to the development of improved animal production, and research is currently under-way to devise appropriate changes in flock management (ICARDA, 1987, 1988).

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Table 1. Soil water at planting to 1 m depth (mm), rainfall during crop growth (mm) and trial mean above-ground dry weights at maturity (kg ha^{-1}).

Trial	Soil water	Rain	Dry weight
1985/86			
Mastung	52	143	438
Dasht	77	137	692
Dasht R[1]	37	137	577
Quetta R	60	220	1155
1986/87			
Khuzdar R	116	162	1664
Kovak R	53	194	1550
Dasht	96	221	2455
1987/88			
Khuzdar PI[2]	133	32	802
Kalat PI	87	51	371
Kovak R	41	107	134
Dasht R	45	147	96
Dasht	26	102	130

[1] "Run-on" site, i.e. one which receives occasional stream-flow irrigations.

[2] Pre-planting irrigation applied.

Table 2. December herbage yields, final straw and grain yields (kg ha^{-1}) and resultant change in gross benefit (R ha^{-1}), 1986/87 ("farm-gate" price of herbage in December 1986 was 0.75 R kg^{-1}).

Trial	Herbage	Straw		Grain		Change in G. Benefit
		Uncut	Cut	Uncut	Cut	
Kovak	57	1176	967	532	406	-304
S.E.$_{var}$	19	177	138	119	75	
S.E.$_{fert}$	10	95	74	64	40	
Dasht	133	1598	1487	1096	999	-137
S.E.$_{var}$	18	269	182	148	167	
S.E.$_{fert}$	10	144	97	79	89	

Table 3. Herbage, straw and grain dry weights (kg ha^{-1}), and gross benefits of mature crop (R ha^{-1}), averaged over all trials.

Variety	Herbage	Straw	Grain	G. benefit
LB7	1237	679 #	361	1093
Wadi Hassa	1215	593 #	352	1053
Tadmor	1315	664 #	377 #	1135
Arabi aswad	1314	643 #	358	1069
Arabi abiad	1614 #	816	370 #	1214
Local	1338	813	307	1107
Mean	1339	701	354	1112
- fertilizer	1283	643	333	1025
+ fertilizer	1395	760	376	1198
S.E.$_{variety}$	88 *	38 ***	20	52
S.E.$_{trial}$	135 ***	59 ***	31 ***	79 ***
S.E.$_{fertilizer}$	51	22 ***	12 **	27 ***
S.E.$_{vxt}$	331	144 ***	76	194
S.E.$_{vxf}$	125	54	29	73
S.E.$_{txf}$	191	83	44 *	112 *

Means marked with '#' differ significantly from the control (Dunnet's test) at $P < 0.05$.

*, **, *** Treatment effects statistically significant at $P < 0.05$, 0.01, or 0.005, respectively.

Table 4. Genotype-environment analyses after Eberhart and Russell (1966) - linear regressions of individual variety parameters against overall site means, $y = a + bx$.

	Herbage (kg ha^{-1})			Grain (kg ha^{-1})		
	r[1]	a	b	r	a	b
LB7	0.94	21	0.85	0.99	-14	1.02#
Wadi Hassa	0.96	-70	1.01	0.98	-5	0.99#
Tadmor	0.96	-76	0.94	0.97	-24	1.12#
Arabi Aswad	0.96	92	0.90#	0.97	-3	1.01#
Arabi Abiad	0.97	-293	1.48#	0.99	11	1.10#
Local	0.85	326	0.82	0.95	35	0.76

	Straw (kg ha^{-1})			Gross benefit (R ha^{-1})		
	r	a	b	r	a	b
LB7	0.88	23	0.95	0.97	-19	1.00
Wadi Hassa	0.92	8#	0.87#	0.98	13	0.92
Tadmor	0.94	-49	0.99	0.97	-111	1.11
Arabi Aswad	0.83	97	0.75#	0.96	57	0.89
Arabi Abiad	0.94	-24	1.21	0.98	20#	1.13#
Local	0.95	-56	1.24	0.98	40	0.95

[1] r, b, a : correlation coefficient, slope and y-axis intercept respectively.

#: slopes or intercepts so marked differ significantly from the local variety values at $P < 5\%$.

Table 5. Linear regressions of individual variety parameters against "water availability index", $y = b(x-x_o)$.

	Herbage (kg ha^{-1})			Grain (kg ha^{-1})		
	r[1]	x_o	b	r	x_o	b
LB7	0.83	124	11.88	0.88	149	4.72
Wadi Hassa	0.78	123	12.91	0.86	146	4.51
Tadmor	0.77	124	11.98	0.84	148	5.06
Arabi Aswad	0.83	117	12.29	0.88	148	4.80
Arabi Abiad	0.86	140	20.63	0.93	147	5.41#
Local	0.80	104	12.06	0.90	141	3.78

	Straw (kg ha^{-1})			Gross benefit (R ha^{-1})		
	r	x_o	b	r	x_o	b
LB7	0.77	110	5.89	0.79	123	10.56
Wadi Hassa	0.84	117	5.65	0.83	122	10.00
Tadmor	0.80	119	5.96	0.74	124	11.02
Arabi Aswad	0.79	103	5.06	0.85	123	10.21
Arabi Abiad	0.91	127	8.34	0.85	125	12.72
Local	0.83	122	7.74	0.77	112	9.66

[1] r, b, x_o : correlation coefficient, slope and x-axis intercept respectively.

: slopes or intercepts so marked differ significantly from the local variety values at $P < 5\%$.

Table 6. Season mean yields (kg ha^{-1}) (excluding the two trials in 1987/88 that received pre-planting irrigation), production costs (R ha^{-1}), labour inputs (hour ha^{-1}), gross and net benefits (R ha^{-1}), and returns to labour (R $hour^{-1}$) for the local and Arabi abiad barley land-races without fertiliser.

	Straw	Seed	Cost	Labour	Benefits Gross	Benefits Net	Returns to Labour
1985/86							
Local	460	222	383	54	562	180	2.5
A. abiad	657	250	398	57	704	306	3.9
1986/87							
Local	1356	607	607	105	1876	1269	12.0
A. abiad	1320	780	697	128	2156	1459	11.2
1987/88							
Local	117	17	321	26	185	-136	-5.2
A. abiad	123	29	327	28	241	-86	-3.1
Average							
Local	748	331	461	68	1015	555	4.5
A. abiad	800	416	505	79	1193	689	5.2

Table 7. Crude protein percentages of Arabi abiad barley, and the local land-races of barley and wheat.

	A. abiad barley	Local barley	Local wheat
Vegetative stage herbage	8.9	10.9	8.5
Flowering stage herbage	7.4	7.6	5.5
Straw	3.5	3.7	3.0
Grain	10.7	9.9	10.1

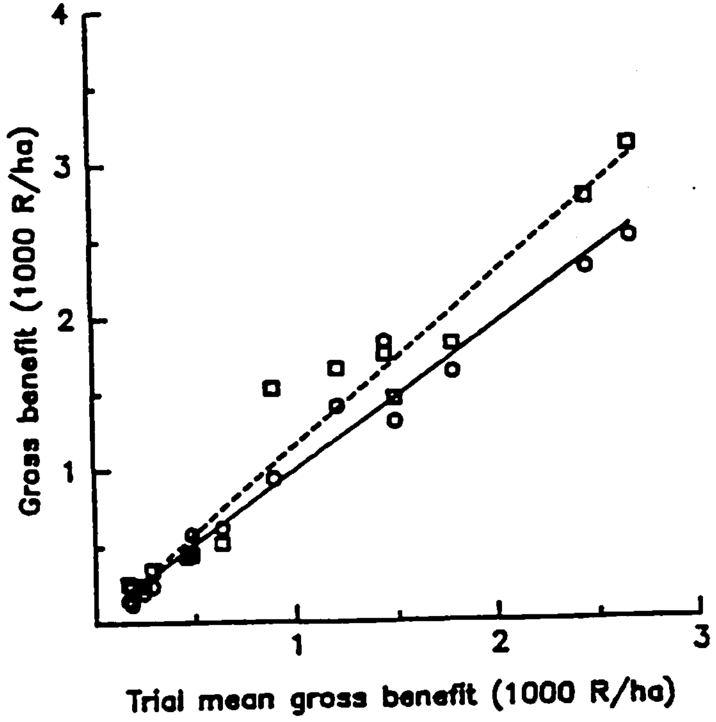

Figure 1. Relation between gross benefits of the local and Arabi abiad land-races and trial mean gross benefits.
o,— Local: $y = 0.95x + 40$; ◻, ---Arabi abiad: $y = 1.13x + 20$

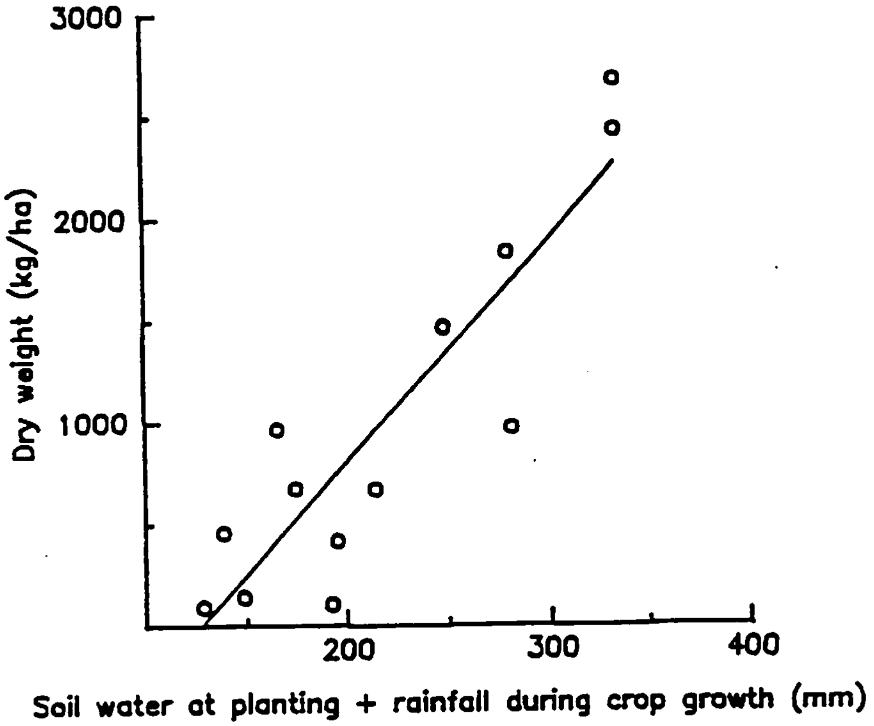

Figure 2. Relation between total above-ground dry weight and (soil water at planting + rainfall during crop growth. $y = 11.2(x-130)$.