Genetic Variability and Climatic Factors Affecting Lucerne Seed Production

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ABSTRACT

Seed yield variation in French lucerne cultivars ranges from 20% below the check to 15% above, but new cultivars often outyield older ones. Climate, age of the crop, yield level and crop management can all influence genetic effects, but usually cultivar seed yield ranking is not changed. Nevertheless, significant cultivar x location interactions can occur, particularly for mediterranean cultivars which tend to have better seed production when grown in the environment in which they were bred.

Climatic factors strongly influence lucerne seed yield. Temperatures between 25 and 30°C increase flower fertility, pollinator activity and seed set, and water supply (excessive or drought), can reduce seed yield. These factors are discussed.

Seed yield is highly correlated with seeds per pod, and also with raceme and pod number. The crop can be managed to increase these yield components, particularly through row spacing (or thinning), time of defoliation, and rationed irrigation. Improved seed yields will come from correct management of high yielding cultivars in an environment favourable for seed production.

Additional index words: **seed yield components, cultivars, temperature, irrigation, management.**

INTRODUCTION

Lucerne seed production is influenced by a number of factors: genetic variability, climate, soil type, pollinator activity, pests and diseases, management, and interactions between these different factors. This paper reviews the first two, i.e. genetic variability, climate and their interactions, and to do this, the following questions have been asked:

* what is the importance of genetic variability?
* are there significant interactions between genetic effects and climate, age of the crop, yield level, crop management or other factors?
* which are the main seed yield components?
* which are the main climatic factors influencing these yield components?
* what are the characteristics of regions favourable for seed production?
* how can management be integrated with local conditions to produce regular, high seed yields?

GENETIC FACTORS

In lucerne, the number of seeds per pod (which vary from 2 to 9) is a strongly inheritable character. A number of studies (Demarly and Chesneaux, 1966; Dattèe, 1972, 1974, 1975) have shown that the number of seeds per pod are not dependent on the number of ovules per ovary (which vary from 8 to 12) but on

(i) the number of fertilized ovules and their ability to develop

(ii) pollen fertility (germination rate must be above 20%)

(iii) the coefficient of parentage, which can greatly reduce the number of ovules able to reach maturity. For example, pollen tubes must be long enough to ensure fertilization (Rice *et al.*, 1970). However, Sayers and Murphy (1966) considered that ovule abortion after fertilization was the main cause of low fertility. When breeding from a narrow base, consanguinity effects can occur (e.g. Table 1), so that now most lucerne cultivars are synthetics (Guy and Dattèe, 1981; Guy, 1988), often with a large number of parental components.

An improved knowledge of lucerne genetics has assisted breeders in improving the seed production potential of lucerne, in USA (Kehr *et al.*, 1982), Italy (Veronesi *et al.*, 1986), Hungary (Bocsa and Buglos, 1983), Czechoslovakia (Kristek, 1979; Mrazkova *et al.*, 1983; Holy and Rod, 1984), USSR (Kirnosov, 1982) and France.

FRENCH CULTIVARS

The National Seed Growers Union (F.N.A.M.S.) began trials in 1961 which continued until 1965. This work showed that seed yields of some cultivars (e.g. cv. Du Puits) were greater than other cultivars and mixed populations. Since 1974 systematic trials have been carried out for all registered cultivars and in the different seed production regions. Up until 1987, 33 cultivars were

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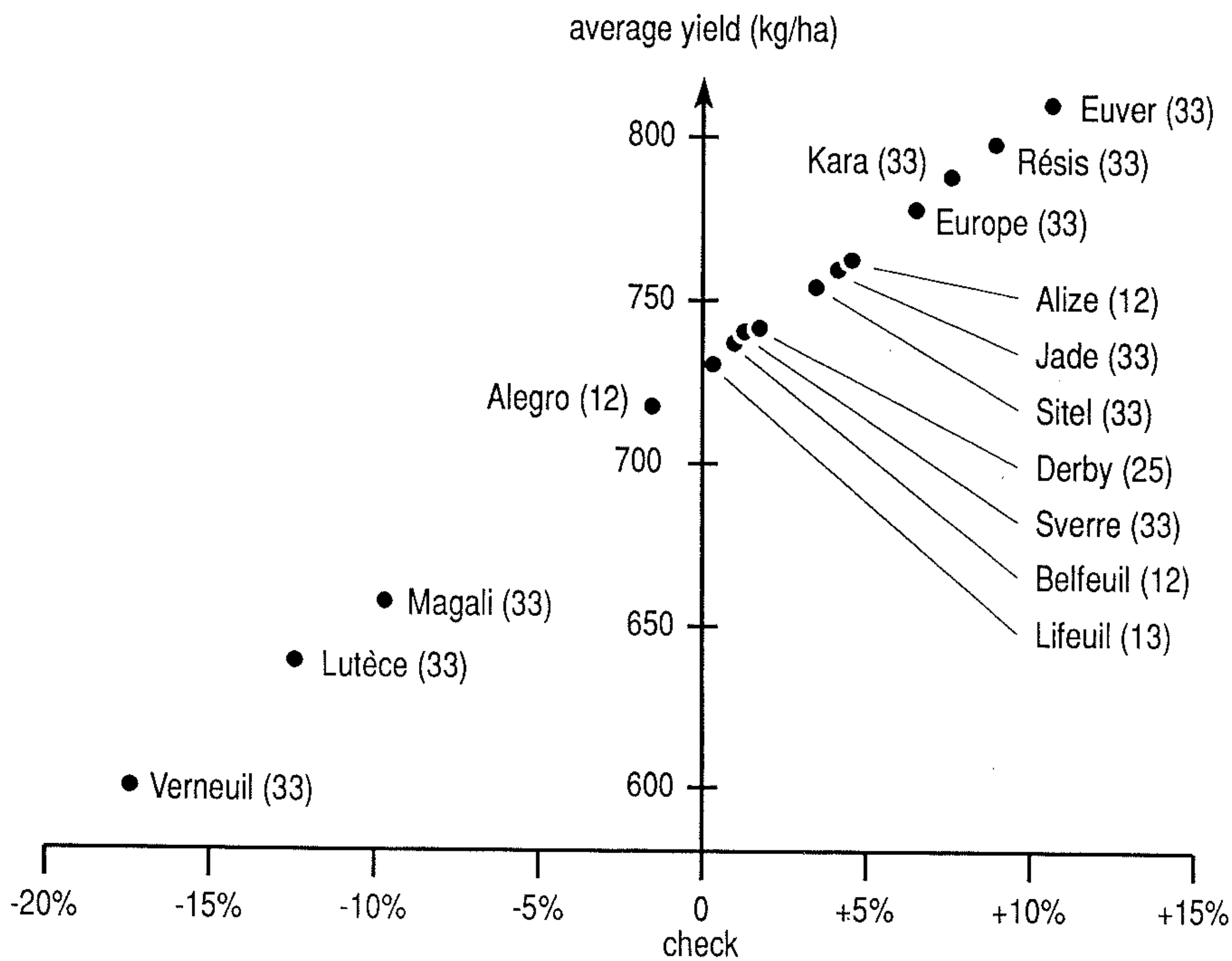
TABLE 1.
Consanguinity effects on fertility in lucerne.

Parental plants	S_0	S_1	S_2	S_3	S_4	HS	Descendants
Pollen germination rate (%)	80	75	67	70	61	-	-
Pods per flower (%)	35	18	23	17	21	76	66
Seeds per flower	0.56	0.18	0.24	0.13	0.14	2.91	2.00
Seeds per pod	1.56	1.00	0.90	0.75	0.86	3.75	2.98
Weight of 1000 seeds (g)	2.52	2.44	2.15	2.26	2.11	2.39	2.32
	with selfing					with crossing	

Figure 1
Seed yields (kg ha^{-1}) of French lucerne cultivars (1980-1987) relative to means of three check cultivars (Europe, Magali, Sitel). Figures in brackets = number of crops.



assessed in 78 trials in 5 locations. Since 1985, these studies have been limited to new cultivars prior to registration.

Results for 15 cultivars trialled between 1980-87 (Fig. 1) show yields varying from 20% below the check (cv. Verneuil) to 15% above the check (cv. Rèsis and Euver). Most new cultivars have outyielded the check (cvs Europe, Magali and Sitel). It should be noted, however, that since 1980, the check yield has increased, e.g. that of cv. Europe increased from 565 kg ha^{-1} to 779 kg ha^{-1}.

INTERACTION STUDIES

Seed yields differ from trial to trial, depending on climate, age of stand, site and management, and it is not generally possible to test the diverse interactions because of the differences in trial conditions and management. However, some effects have been observed:

(i) Average yield/cultivar yield

Linear regressions for cultivar yield and mean trial yields (Fig. 2) have produced coefficients of around 0.98. Cultivar ranking was not altered by the mean yield, but differences between cultivars increased, e.g. the seed yield difference between cultivars Verneuil and Rèsis was 81 kg ha^{-1} when the mean trial yield was 200 kg ha^{-1}, but was 301 kg ha^{-1} when the mean trial yield was 1200 kg ha^{-1} (Fig. 2).

Figure 2
Relationship between cultivar seed yields and mean trial seed yields.

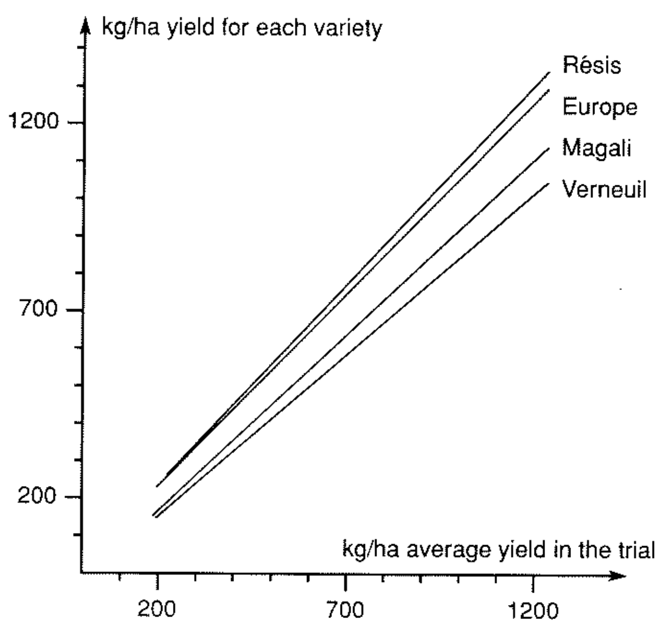
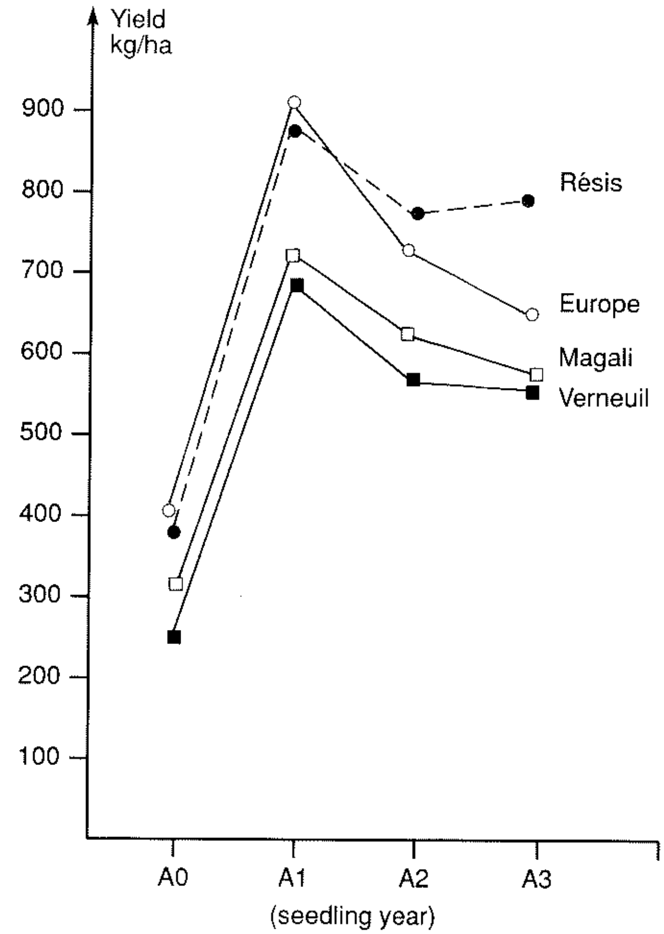


Figure 3
Effect of stand age on seed yield of four lucerne cultivars.



(ii) Stand age

Seed yield was always low in the seeding year, and reached a maximum in the first year after seeding (Fig. 3). Cultivar ranking did not differ markedly with stand age for the first three harvests, but at the fourth harvest, cultivar differences increased, e.g. cv. Rèsis outyielded cv. Europe (Fig. 3).

(iii) Location x cultivar

No significant interactions were recorded, in that cultivar ranking was reasonably consistent irrespective of location. However, mediterranean cultivars produced greater seed yields at mediterranean sites. For example at Montpellier, cvs Magali, Cinna and Livia produced seed yields similar to the check (cv. Europe), but at sites to the north west (Lectoure) and north east (Valence), yields were only from 60 to 80% of that of the check. A significant interaction between cultivar and location has been reported from Eucarpia trials, when 14 cultivars from different origins in Europe were tested in six countries (Rod *et al.*, 1986), Table 2.

TABLE 2.
Seed yield of 7 European cultivars relative to the check cultivar Europe, at 6 sites in 1980-82.

Cultivar	Plaussig DDR	Zelesice CSSR	Osijek Yugosl.	Lusignan France	Kompolt Hungary	Pleven Hungary
Europe	100	100	100	100	100	100
Bobrava	49	100	87	123	111	114
Palava	58	81	101	103	104	98
Grimma	61	78	64	122	98	94
Verko	45	77	102	93	94	102
Osjecka	43	55	71	95	90	86
Magali	42	44	48	82	81	98
Pleven	37	39	41	72	85	101

SEED YIELD COMPONENTS

Many authors have reported correlations between seed yield and yield components (Table 3), and seed number per pod is usually highly significant. The number of racemes and pods per raceme are also important characters. Seed yield and seed weight are often negatively correlated, e.g. Pedersen (1962) found that seed weight was highest in the lowest yielding cultivar, and *vice versa*. It is possible to breed lucerne for both forage and seed yield (Veronesi *et al.*, 1986; Falcinelli and Veronesi, 1984), as the two characters are related. Interestingly, root carbohydrate content was also highly correlated with seed yield (Table 3).

CLIMATIC FACTORS

Blondon *et al.* (1979) examined temperature and light effects on seed yield in phytotron studies, and found that pollen fertility and hence the number of fertilized ovules per ovary increased as temperature increased (Table 4). High temperature (25-30°C) also promotes pollinator activity and seed set (Delaude, 1972), and seed yield usually increases as temperature at anthesis increases (Fig. 4), Delaude (1976). This response can be modified by water supply (Fig. 5), Delaude (1980), being reduced in cases of deficiency (Delaude, 1973) or excess (Fig. 5).

The climate in the best lucerne seed producing areas is characterized by a low summer rainfall, good sunlight

TABLE 3.
Correlations between seed yield (or weight per plant) and diverse yield components.

References	Racemes per stem (or plant)	Pods per raceme	Seeds per pod	Seed weight	Green matter weight	Root carbohydrate content
Dann and Waldron, 1933	.54*	.68**	.57**		.73**	
Pedersen and Nye, 1962		S*	S*	- S*		
Hurst and Pedersen, 1964	.13	.10	.48**	-.10		
Demarly and Chesneaux, 1966			.62	-.18	.72**	
Dobrenze and Massengale, 1966		S*	S*			.93**
Dovrat *et al.*, 1969	S*	S*				.90*
Rumbaugh *et al.*, 1971	S**		.52**	.06	.73**	
Steuckardt, 1973	S***		.65**			
Zharinov, 1978			S**			
Taylor and Marble, 1986	.84**		.77**			
Boçsa and Buglos, 1983			.58**			

*P<0.05, **P<0.01, ***P<0.001, S = significant (correlation not stated)

Figure 4
Relationship between temperature during anthesis (June) and seed yield in the 'Tarn' region (data from FNAMS 1967-1972).

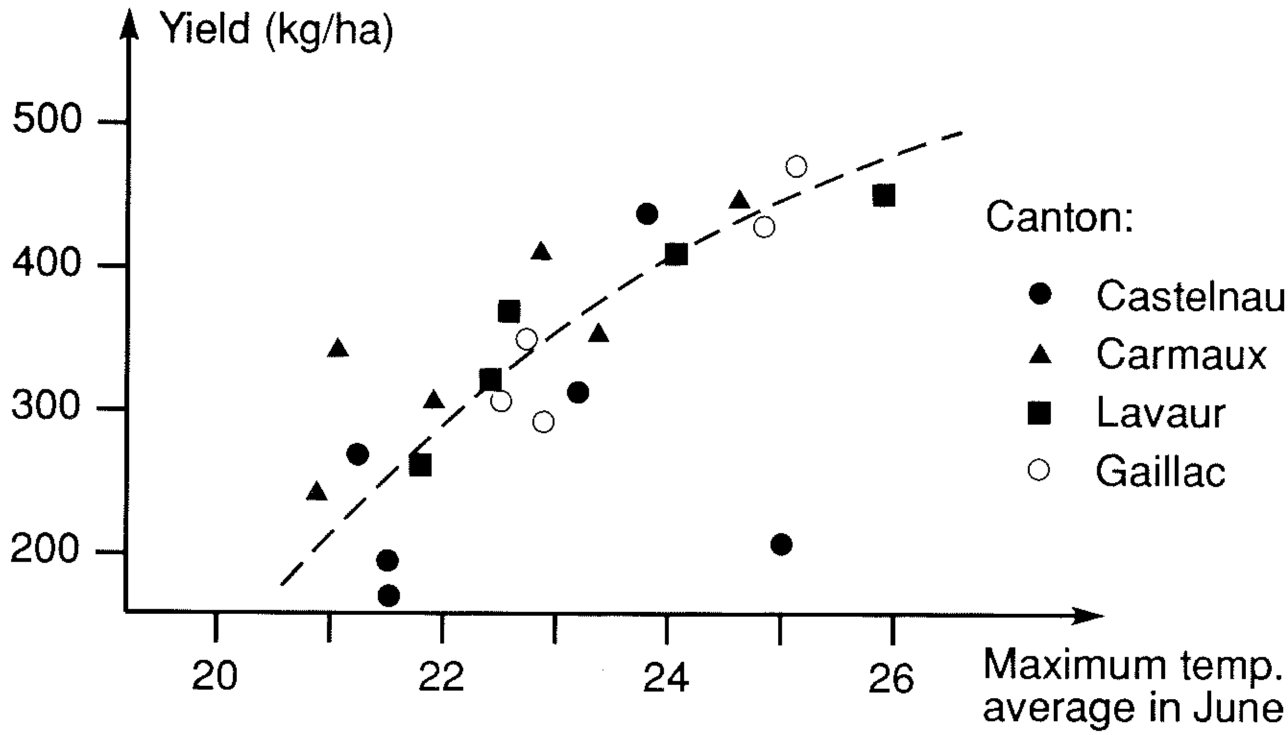


Figure 5
Relationship between rainfall during anthesis and harvest (June and July) and seed yield in the 'Gars' region (data from FNAMS 1970-1978).

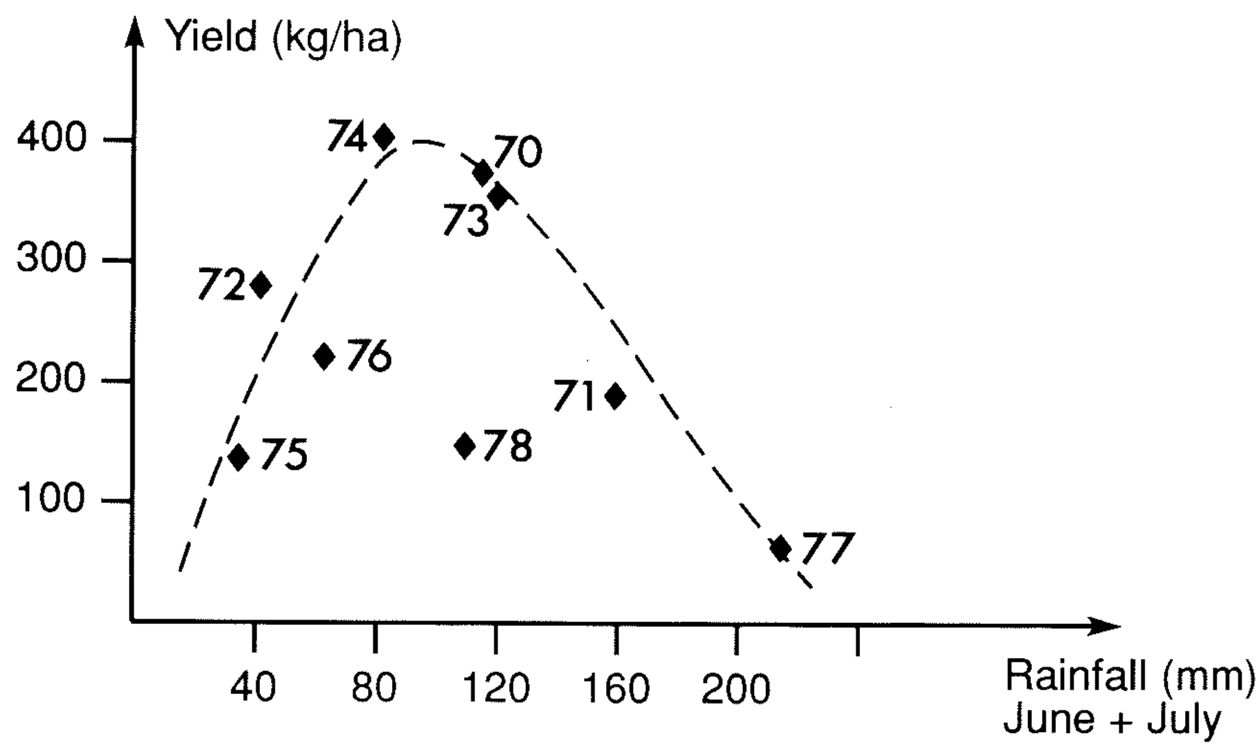


TABLE 4.
Effect of temperature on lucerne pollen and ovule fertility (after Blondon *et al.*, 1977).

Temperature °C	%pollen fertility	fertilized ovules per ovary
17	32	4.7
22	51	5.6
27	74	6.2

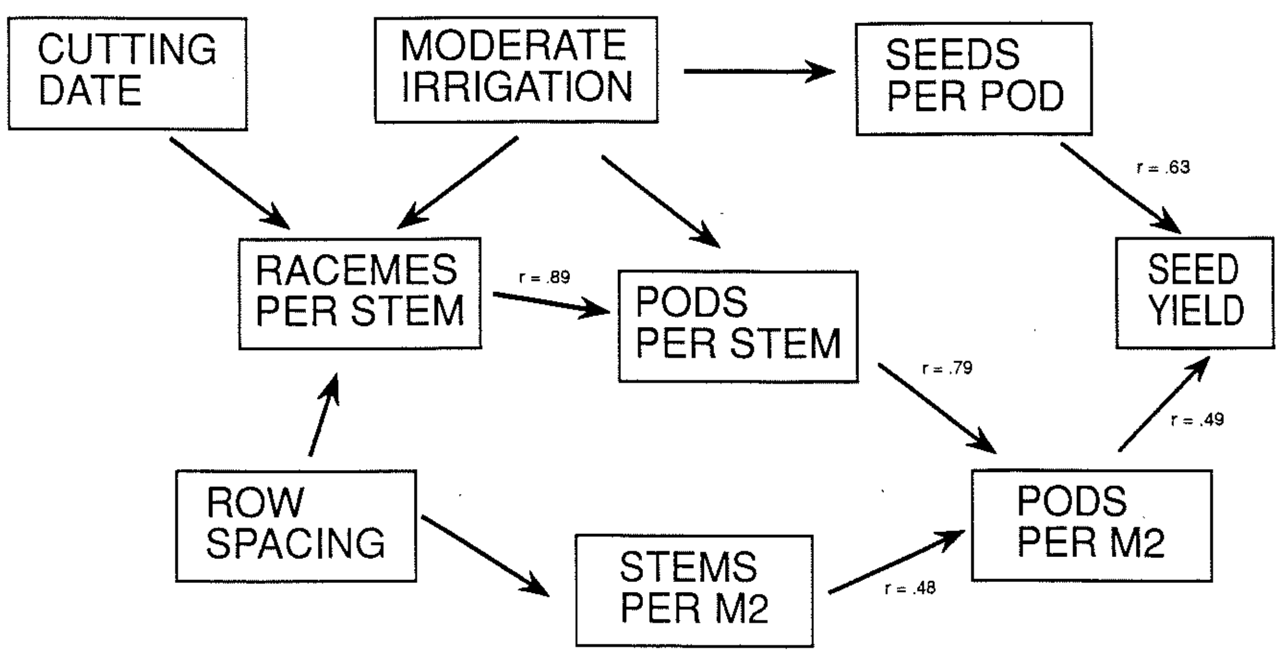
and high temperatures (Rumbaugh *et al.*, 1971; Rincker *et al.*, 1988; Hacquet, 1989). Excessive water encourages vegetative growth (Fick *et al.*, 1988), leading to lodging and competition with reproductive growth. Moisture stress reduced stem and raceme number, number of seeds per pod and thousand seed weight (Fick *et al.*, 1988), although the number of flowers was generally not affected over a moderate range of moisture stresses.

In a French survey involving 46 observations over three years, Hacquet (1988) attempted to relate climate to seed yield and its components. While yield was correlated with seeds per pod and pod number (Fig. 6), no relationship with any single climatic factor was established, because they tend to interact and are complex.

MANAGEMENT

A number of studies have reported the influence of row spacing and thinning (Pedersen and Nye, 1962; Dovrat *et al.*, 1969; Rincker, 1979; Kowithayakorn and Hill, 1980; Lovato and Montanari, 1988), cutting time (Dovrat *et al.*, 1969; Hacquet, 1986, 1987) and irrigation (Abu-Shakra *et al.*, 1969; Peyremorte, 1974; Taylor and Marble, 1986), and the influence of these factors on yield components is summarized in Figure 6. Also vital of course, is pollinator supply and activity (Rincker, 1979; Marble, 1989).

Figure 6
Correlations between seed yield and seed yield components (data from 46 observations in different French regions, FNAMS 1978-1988).



CONCLUSION

While good management can improve seed yields, production is always dependent on the environment, and particularly the hazards of adverse weather. Rincker (1964-68) found yields from 0 to 2110 kg ha^{-1} depending on season. The production of consistently good seed yields will therefore depend on:

* plant breeding to produce cultivars with good potential seed yields
* careful choice of site to provide climatic requirements
* careful and correct management.

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