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The heuristic value of mathematical modelling for elucidation of the honey production dynamics of *Apis mellifera* colonies

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A mathematical model of the honey production dynamics of non-swarming domesticated *Apis mellifera* colonies in temperate zones is presented. This is achieved by constructing a model interconnecting the intracolonial population dynamics, equations describing honey consumption and production, and a function describing the nectar availability during the season. The model can handle a range of colony growth and phenological patterns. It is specifically shown to generate results in accordance with empirical data from the southeastern part of Norway. Furthermore, a brief elaboration is given of its heuristic attributes that are likely to define and optimize the experimental work needed for obtaining a thorough understanding of honey production dynamics.

Key words: *Apis mellifera*, dynamic model, honey production, mathematical modelling

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In most branches of natural science there is a continuous interplay between theory and experiment. In biology this interplay is much weaker and in some areas non-existent. To a considerable extent, honeybee research qualifies as such an area, and it suffers from non-assimilation of facts because large amounts of data are collected without reference to explicitly stated explanatory concepts.

In physics, for example, mathematical modelling is an important ingredient for the development of the theoretical foundation of dynamic processes by integrating the explanatory concepts into a coherent hypothetico-deductive structure. There is no *a priori* reason why this should not be so in the study of the dynamic aspects of the honeybee society. In fact, the reasons are only historical and cultural, and as stated by Glass & Mackey (1988): «somehow, a myth has arisen that detailed mathematical and theoretical analyses are not appropriate in biology. Yet if the complex dynamic phenomena that occur in biological systems were to arise in some inanimate physical system - let us say in a laser, or liquid helium, or a semiconductor - they would be subjected to the most sophisticated experimental and theoretical study».

In the development of the theoretical or explanatory foundation of a given dynamic process or system, mathematical models may serve a heuristic function in several ways. However, their main heuristic attributes are:

(i) the capability of interconnecting a wealth of empirical data into a coherent whole, thereby enlarging the applicability of these data;
(ii) the capability of enforcing a more explicit statement of, and elucidating the qualitative as well as quantitative consequences of different hypotheses, thereby increasing their testability;
(iii) the capability of initiating and canalizing further theoretical and experimental work by drawing attention to which key issues must be resolved, as well as clarifying which data are required.

The seasonal honey yield of a honeybee (*Apis mellifera*) colony is dependent on several intracolonial as well as extracolonial conditions and thereby qualifies as a complex dynamic process not easily elucidated by descriptive or experimental methods alone. In fact, it is reasonable to assume that we already have access to all the main explanatory concepts needed. However, we are far from providing a proper integration of these concepts into a coherent hypothetico-deductive framework within which the different factors contributing to honey yield may be quantitatively analysed. Most of the studies published in the field document this very clearly by their focus on a few parameters at a time, and by their one-sided emphasis on descriptive methods (Farrar 1937, McLellan 1978, Szabo 1980, Woyke 1984, Milne 1985, Rinderer et al. 1985, Bühlmann 1986, Ratnieks 1986).

The main aim of this paper is to contribute to the establishment of a hypothetico-deductive framework, by suggesting a preliminary mathematical model together with a brief elaboration of its heuristic attributes.

If we succeed in building realistic models, they may be of considerable help in designing optimal management procedures, the study of the quantitative effects from various diseases, and honeybee breeding by elucidating how honey and pollen production depends on various behavioural and morphological attributes of the queen and the workers.

MODEL PRESENTATION

The dynamics of non-swarming domesticated colonies in temperate zones, from early spring to late autumn, may be approximated as

$$dW_1(t)/dt = a_0 \cdot W_1(t) \cdot [(K_0 - W_1(t))/K_0] \cdot (W_4(t) + W_5(t) + W_6(t)) \cdot [(K_1 - W_4(t) - W_5(t) - W_6(t))/K_1] \quad (1)$$

$$dW_2(t)/dt = a_1(t) \cdot W_1(t) - a_1(t-8) \cdot W_1(t-8) \quad (2)$$

$$dW_3(t)/dt = a_1(t-8) \cdot W_1(t-8) - a_1(t-21) \cdot W_1(t-21) \quad (3)$$

$$dW_4(t)/dt = a_1(t-21) \cdot W_1(t-21) - a_1(t-21-N_p) \cdot W_1(t-21-N_p) \quad (4)$$

$$dW_5(t)/dt = a_1(t-21-N_p)\cdot W_1(t-21-N_p) - a_1(t-21-F_f)\cdot W_1(t-21-F_f) \quad (5)$$

$$dW_6(t)/dt = a_1(t-21-F_f)\cdot W_1(t-21-F_f) - N_f(t-W_m)\cdot a_1(t-21-W_m)\cdot W_1(t-21-W_m) - F(t) \quad (6)$$

where

$$a_0(t) = \begin{cases} c_1, & W_4(t)+W_5(t)+W_6(t) \le K_1, \\ c_2, & W_4(t)+W_5(t)+W_6(t) > K_1, \end{cases} \quad (7)$$

$$N_f(t) = \begin{cases} 1.0, & R(t) \le (1/R_{lim}), \\ 1.0/R(t)\cdot R_{lim}, & R(t) > (1/R_{lim}), \end{cases} \quad (8)$$

$$R(t) = W_4(t)/(5/8)\cdot W_2(t) \quad (9)$$

$$F(t) = \begin{cases} 3\cdot b_1\cdot W_6(0)/p, & 0 < t \le p/3, \\ 3\cdot b_2\cdot W_6(0)/p, & p/3 < t \le 2p/3, \\ 3\cdot b_3\cdot W_6(0)/p, & 2p/3 < t \le p, \\ 0.0 & t > p. \end{cases} \quad (10)$$

Furthermore, $W_1(t)$ is the number of female eggs laid daily by the queen at time t; $W_2(t)$ is the number of open worker brood cells in the colony at time t. An egg is counted as open brood immediately after it is laid; $W_3(t)$ is the number of sealed worker brood cells at t; $W_4(t)$ is the number of young workers (hive bees) of age $\le N_p$ days; $W_5(t)$ is the number of workers of age $> N_p$ days and $\le F_f$ days; $W_6(t)$ is the number of workers of age $> F_f$ days; $a_0(t)$ is the queen's and the workers' capability to influence the queen's egg-laying rate; K_0 is the queen's maximum daily egg-laying capacity; K_1 indicates the number of worker bees present in the colony when the queen's egg-laying capability becomes inhibited by them; $a_1(t)$ is the proportion of open worker brood cells that survives until sealing (assumed to be unity throughout this study); $W_1(t-8)$, $W_1(t-21)$, $W_1(t-21-N_p)$, $W_1(t-21-W_m)$ are the number of eggs laid respectively 8, 21, $(21+N_p)$, $(21+F_f)$ and $(21+W_m)$ days earlier; N_p is the time period a worker normally spends as a nurse; F_f is the mean age of workers on their first day of foraging; W_m is the mean longevity of summer worker bees; c_1 is a constant describing the queen's innate physiological capability to increase her egg-laying rate multiplied by a term expressing the workers' per capita capability of influencing it, and c_2 is a constant describing how strongly the workers are able to inbibit the queen's egg-laying rate; $N_f(t)$ is a function describing the fraction of eggs that develops into adults becoming nurses; $1/R_{lim}$ is the level which the ratio of young workers to open brood must exceed before winter bees can develop; $F(t)$ is the the mortality rate of the overwintered population; p is the number of days from the beginning of the season until all worker bees from the overwintered population are dead; b_1, b_2 and b_3 are the proportions of the overwintered population that die in three equally spaced intervals during period p; $W_6(0)$ is the number of overwintered bees at the beginning of the season.

Somewhat simpler versions of this population model have been published earlier. These models were shown to generate predictions in close accordance with empirical data of honeybee colony demography (Omholt 1986, 1988a), and those papers should be consulted for a comprehensive validation of the different terms and equations. However, one important point ought to be repeated here: The main premise of the model is that the unimodal (or bimodal) brood-rearing pattern observed in non-swarming colonies in temperate zones is to a greater extent caused by intracolonial factors than by extracolonial factors. This presumption receives considerable support from the observations of Wille (1985), who found that in Switzerland the annual demographic patterns of colonies from various races were extremely stable compared to weather and forage conditions.

Presuming sufficient stores, the seasonal honey yield pattern (H_y) from a colony may be approximated by

$$H_y = \sum_{t=0}^{S} \{N(t)\cdot Q(t) - e\cdot W_2(t) - h(t)\cdot[W_4(t)+W_5(t)+W_6(t)]\} \qquad (11)$$

$$\text{where } h(t) = \begin{cases} h_1, & t < u \\ h_2 & u \leq t \leq S; \end{cases} \qquad (12)$$

and Q(t) is the number of foragers; N(t) is the mean amount of honey that is obtained from the nectar gathered per forager per day; e and h(t) indicate the mean daily honey consumption per worker larva and adult; h_1 and h_2 are constants; u is the day when the metabolic activity switches to a higher level in the spring as a result of more favourable intra- and extracolonial conditions; S is the season length and it is presumed to be 180 days in this study, which should be wide enough to include the length of the productive season for most colonies in temperate zones.

The mean amount of honey brought home by a successful forager per day (N(t)) is dependent on several factors, such as the flight distance between the flower patch and the hive, interflower flight time, handling time per flower, delivery time per load in the hive and total daily foraging period (Schmid-Hempel et al. 1985). In addition, the weather conditions influence several of the factors listed above. Thus any comprehensive elaboration of N(t) for the present would be rather premature. Fortunately, in most situations where the present model may be of some value, it is not necessary to incorporate an advanced description of N(t). In most areas of temperate zones the phenological pattern may be approximated by a uni-, bi- or tri-modal pattern (Mitchener 1955, Lunder 1971). It is no problem to define functions that generate such patterns. In order to avoid unnecessary complexity a function capable of generating several types of unimodal patterns is chosen in this paper. It has the structure:

$$N(t) = \begin{cases} 0.0, & t \leq T_s \\ n_{max}\cdot h_{max}\cdot[1/Z(p,q)]\cdot t^{p-1}\cdot(S-T_s-t)^{q-1}, & T_s < t \leq T_e \\ 0.0, & T_e < t, \end{cases} \qquad (13)$$

where h_{max} is the mean amount of honey (including 15% water) gathered per forager per trip; n_{max} is the mean maximum number of trips per forager per day under abundant forage conditions; T_s and T_e are respectively the first and last day of nectar foraging in the season; Z(p,q) is a normalization factor securing that $(N(t)/n_{max}\cdot h_{max})$

≤ 1.0. By varying the constants p and q different nectar flow patterns may be simulated (Fig.1). In the following, h_{max} and n_{max} are presumed to be 15 trips/forager/day and 12 mg honey/forager/trip respectively. Of course, these figures will vary somewhat, but the above values are based on data from abundant ling heather (*Calluna vulgaris*) flow in Norway (Ukkelberg 1978), and from Winston (1987).

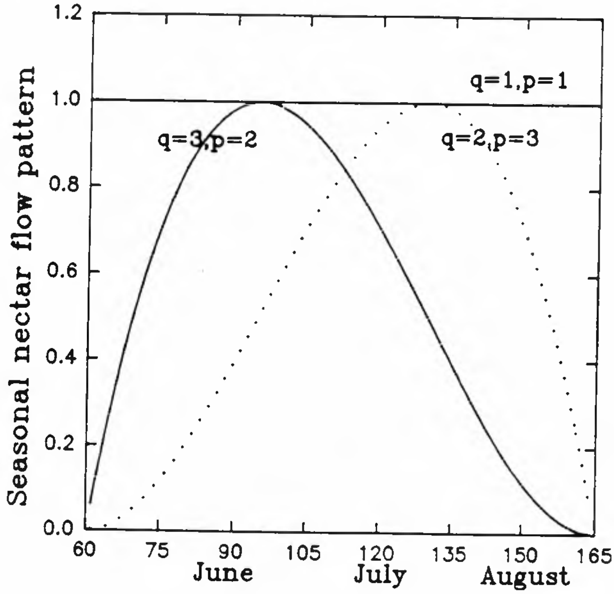

Fig. 1. Different distributions of seasonal nectar flow obtained from equation (13) divided by $n_{max} \cdot h_{max}$

The number of foragers (Q(t)) during the season can be illustrated by different equations, depending on what factors are thought to be important in regulating the structure of the forager population. The following three equations are presumed to be the most likely candidates

$$Q(t) = W_6(t) \quad (14)$$
$$Q(t) = W_6(t) - r \cdot \text{Number of winter bees} \quad (15)$$
$$Q(t) = p(t) \cdot W_6(t) - r \cdot \text{Number of winter bees} \quad (16)$$

Equation (14) indicates that the number of foragers equals the number of workers older than F_f days including all overwintered workers in the spring.

As the foraging behaviour of long lived winter bees may be quite different from that of short lived summer bees (Merz et al. 1979), the inclusion of the process of winter bee creation is also considered to be necessary in a honey production model. In Omholt (1988a) the dynamics of winter bee creation is specifically dealt with. Whether or not the proposed underlying explanatory scheme of this dynamics is correct, is of minor importance in the present context, as long as the equations are able to mimic the process of winterbee creation. In fact, the same is true for the population model as a whole. Equation (15) incorporates this by indicating that a fraction (r ≤ 1) of the winter bees created in the actual year does not participate in foraging.
In addition, equation (16) includes the function p(t) ≤ 1 (cf. legend to Fig. 3) to describe the portion of the overwintered population that does not become foragers in the

spring because of lack of nectar availability and inclement weather conditions. The latter factor is likely to force a considerable part of the population to stay in the hive, in order to keep the brood population warm.

The foraging period is assumed to be constant and independent of the foraging intensity. This latter premise is apparently in conflict with the results obtained by Neukirch (1982) and Wille et al. (1985). However, their data are not particularly conclusive as to how strongly the foraging period is dependent on the foraging intensity. Therefore, until more conclusive data become available, the foraging period ought to be kept constant, and in the following it is set at 11 days (Sekiguchi & Sakagami 1966, Neukirch 1982).

The age at which a non-overwintered bee starts foraging is dependent on intra- as well as extracolonial conditions, and it seems to vary considerably (Lindauer 1953, Neukirch, 1982, Sekiguchi & Sakagami 1966). However, to avoid unnecessary complexity at this stage, the forager population is presumed to consist of bees older than 20 days.

According to Allen (1959), the mean oxygen consumption of an open larva per hour is about 0.1 ml. This corresponds to a value of e of approximately 3.25 mg honey/larva/day.

The metabolic rate of workers varies according to the type of activity they are performing. In early spring when the brood population is of moderate size and the forage conditions are sparse, a considerable fraction of the colony is likely to stay at a resting metabolic level with a thorax temperature lower than 30 °C. Honey consumption rates in the spring confirm this (Lunder 1971). The mean honey consumption per worker is therefore supposed to be expressed by two constants, h_1 and h_2, where h_1 applies to early spring conditions and h_2 to the rest of the season. h_1 and h_2 are supposed to be 8.0 and 15.0 mg honey/worker/day respectively. These figures can be validated by the results of colony metabolic rates obtained by Southwick (1982). It should be noted that h(t) is assumed to express the average consumption for all workers in the colony, field bees as well as hive bees. The expression $h(t)\cdot(W_4(t)+W_5(t)+W_6(t))$ is of course a rather crude approximation that ought to be refined in future models. However, it suffices in the present context as long as the aim is just to have a term that gives an approximately correct picture of colony metabolism.

The present model neglects the influence of various pollen foraging strategies on honey production. Since there is great variation in the yearly amount of pollen foraged, and since each time unit spent on pollen foraging means that there will be one time unit less to spend on nectar foraging, this relationship ought to be included in future models. Because of the paucity of relevant empirical data this would be rather premature for the present. An integration of the pollen foraging dynamics would also be of value for its own sake.

Drone production does have an impact on the honey production dynamics, but in the interests of simplicity this has not been included here. However, in principle, it is no problem to include a drone production model like the one suggested by Omholt (1988b).

RESULTS AND DISCUSSION

Colony weight gain data for seven years (1983-89) from the same apiary located in the southeastern part of Norway were chosen as preliminary test data of the model (Fig. 2). These data were obtained by a national weight gain recording system administered by the Agricultural University of Norway since 1943. Of course, weight gain pattern is not synonymous with honey gain. However, to a large degree, the real honey gain may be approximated by the weight gain because there will be a balance between the evaporation of excess water from the nectar foraged on beforehand and the gain of excess water from the incoming nectar (Kettner 1961, McLellan 1977). Thus, only for those days with a large weight gain preceded by a stop in the nectar gain for several days, is there reason to assume a marked difference between weight gain and honey gain patterns. Unfortunately, no exact population data about the actual colonies were available. However, based on the estimations of number of frames covered with bees given (Burgett & Burikam 1985), a model colony was generated by the population model having a demographic pattern in accordance with these data (Fig. 3). The depicted pattern is also typical for colonies in the southern and central parts of Norway. Fig. 3 also shows the development of the forager population according to equations (14) and (16), in which identical forager populations from late spring to late summer are described, but in which different values are given in early spring and early autumn. When dealing with early and late honey flows one ought to take note of this.

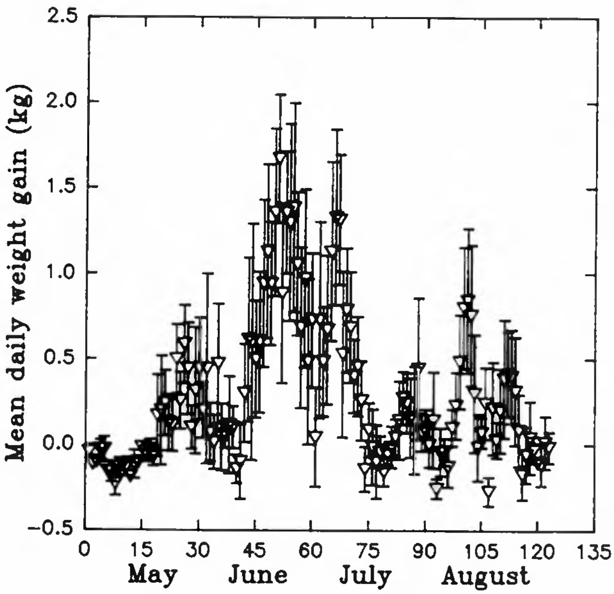

Fig. 2. Mean daily weight gain (± SE) for one colony in the same apiary in the southeastern part of Norway for seven years

To obtain an approximate description of the phenological pattern behind the weight gain data depicted in Fig. 2, the data were calibrated by adding predicted honey consumption and by dividing by the predicted number of foragers (Fig. 4). The forager population was calculated using equation (14), but when equations (15) and (16) were used there was only a minor effect upon the pattern depicted. As may be seen, quite

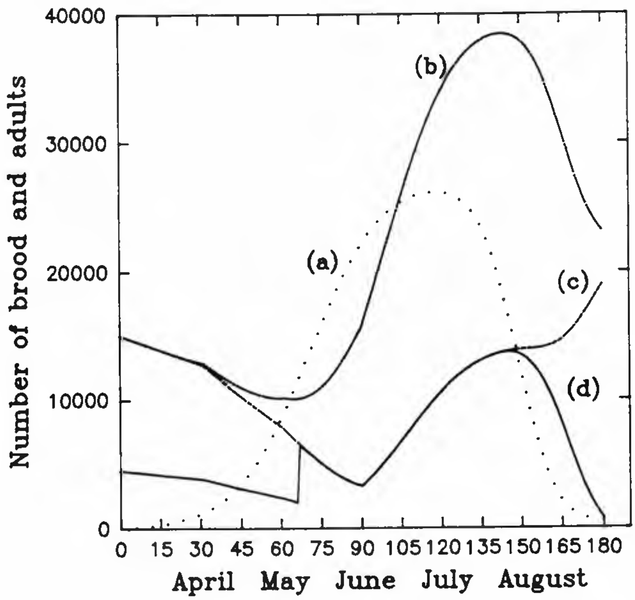

Fig. 3. Growth pattern of a representative «model» colony. (a) amount of sealed and open brood; (b) total number of workers; (c) number of foragers according to equation (14); (d) number of foragers according to equation (16), where r = 1 and p(t) = 0.3 when t ≤ 60 and 1.0 when t > 60

another phenological pattern is generated, and this may be approximated by the function described by equation (13). By using one of the graphs depicted in Fig. 1 the model seems capable of predicting rather realistic results (Fig. 5). This indicates that an approximate N(t) may suffice in most situations, and that the model captures the most essential features of the honey production dynamics. It should be stressed that it represents no problem to generate an almost 100% fit between results and experimental data. However, this would be rather uninformative as the main purpose of honey production models is to study how the dynamics depend on various factors. For this type of analysis it is most convenient to have functions, like the one illustrated in equation (13), that can be modulated to yield a whole spectrum of various phenological patterns.

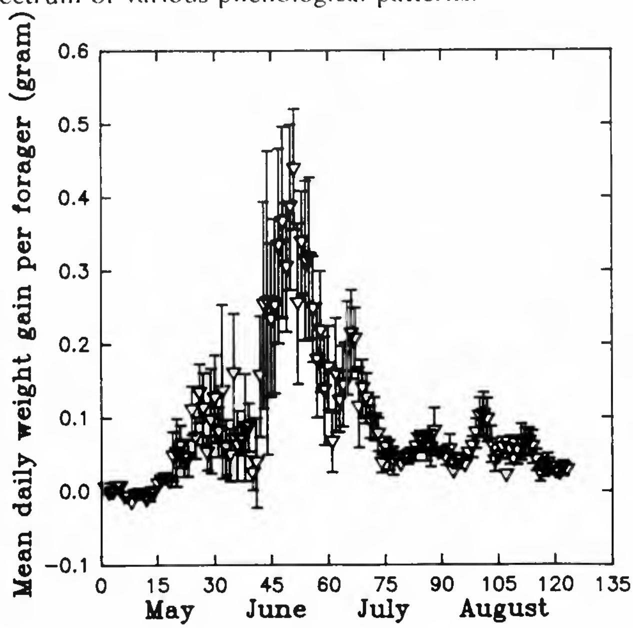

Fig. 4. Mean daily weight gain per forager (± SE) obtained by adding predicted honey consumption to the data in Fig. 2 and dividing by the forager population depicted in Fig. 2 (c)

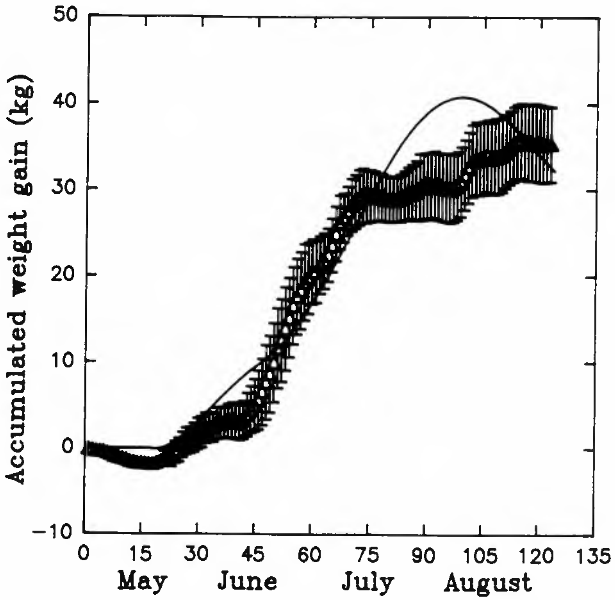

Fig. 5. Comparison between accumulated weight gain obtained from the data in Fig. 2 and predicted accumulated weight gain based on the model population in Fig. 3 and the seasonal nectar flow depicted in Fig. 1 ($q = 3, p = 2$)

One should note that the calibrated weight gain function (Fig. 4) does not drop below zero but stays very close to zero in periods with little or no foraging. This implies that the predicted daily honey consumption for almost all days without or with almost no foraging activity is greater than or equal to the weight loss for these days. This shows that the model gives a rather sound description of the honey consumption dynamics. In fact, the seasonal honey consumption of the model colony depicted in Fig. 3 is predicted to be 57 kg. This is in agreement with empirical honey consumption data of temperate colonies (Weipple 1928, Rosov 1944, Seeley 1985).

It is evident that the model presented interconnects many different types of empirical data into a coherent whole, and thereby enlarges the applicability of these data. It suffices to mention the data concerning the egg-laying capacity of queens, colony demographic patterns, longevity of workers, division of labour of workers, metabolic rates, the generation of winter bees and their behaviour and phenological patterns.

It is also clear that the model enforces a more explicit statement of various hypotheses, thereby increasing their testability. This is automatically secured during the algorithimization of the model. Otherwise, there would be no computer program to run. In this way many hidden premises, which would otherwise have gone unnoticed, will be brought to the surface. It ought to be noted that all the premises of the model, including also those which are not explicitly stated, define a set of more or less interrelated hypotheses. The results (i.e. predictions) may be looked upon as the unfolding of the innate logical structure of this set. This implies that an explicit elucidation of one single hypothesis is very difficult in a complex model as long as there will normally be several additional premises (i.e. hypotheses) without a clear experimental corroboration. However, from the pragmatic point of view this is no serious problem as long as sensitivity analyses show that predictions obtained by application of a specific premise are rather insensitive to modifications of the other uncorroborated premises. If this is not the case, care should be taken when interpreting the results of a model.

The last heuristic attribute of mathematical models listed in the Introduction also applies here. That is, the model is capable of initiating and canalizing further theoretical and experimental work by drawing attention to which key issues must be resolved, as well as clarifying which data are required in order to obtain further understanding. Key issues that must be resolved are for example: how important is the feedback relation between nectar flow and brood rearing; how important is the feedback relation between nectar flow and worker longevity; the influence of various pollen foraging strategies on honey production dynamics.

New data required are primarily comprehensive data sets obtained from specific colonies. Thus, as many parameters of the model as possible should be measured simultaneously on a seasonal basis. This is a very efficient way of constraining the model's parameter space to such an extent that its main weaknesses can be detected, thereby preparing the ground for the construction of more realistic and practical models.

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Changes in the content of soluble solids and titratable acids in apples during ripening and storage

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Changes in the content of soluble solids and titratable acids of apples during ripening and storage were studied at Ullensvang Research Station, Western Norway over a period of three years (1986-88). The effects of different harvest dates of four apple cultivars were examined. Soluble solids increased during the harvest season and this should be taken into consideration by the growers when determining time of harvest. Soluble solids declined during refrigerated storage at a monthly rate of 0.2-0.5 %. The content of titratable acids decreased during both the harvest season and storage, but with different patterns and rates of decline for the cultivars examined. A satisfactorily high soluble solid:titratable acid ratio was reached after some weeks of storage for most of the cultivars.

Key words: Apples, harvest time, ripening, soluble solids, storage, titratable acids.

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The content of soluble solids and of titratable acids are two important quality parameters of apples primarily because of their direct influence on taste and flavour (Whiting 1970; Kvåle 1963; Redalen 1980). Since Norwegian apple production is located at approximately 60°N with a short growing season, these quality parameters and the balance between them are of particular importance. It is well established that the content of soluble solids is the most important quality parameter of Norwegian-grown apples (Kvåle 1969, 1973; Landfald 1972; Redalen 1980). Experience has shown that the earliest ripening cultivars in particular are often low in soluble solids.

Vangdal (1985) published the threshold values as accepted by a taste panel for both soluble solid content and the soluble solid:titratable acid ratio in apples. Threshold values for soluble solids in apples to be sold on the domestic market were introduced to the official Norwegian guidelines (NS2801 A) during its last revision (Norges Standardiseringsforbund 1986).

Since Norwegian consumers prefer apples with a relatively high content of titratable acids (Sekse 1990), the reduction in acids during storage is important and should be taken into account in determining the optimal date for the termination of the storage season.

It is well known that these quality parameters are influenced by time of harvest and that differences in quality as a result of different harvest times are even more marked during the subsequent storage period (Vestrheim 1970). It was, however, of interest to examine the variation in these quality parameters in apples as a result of different harvest times and the duration of the storage period in relation to the threshold values established in the new Norwegian guidelines.

Changes in different quality parameters of apples during ripening and storage were studied over a three-year period in an experiment with different harvest dates of apples. This paper presents the results from this experiment concerning the content of soluble solids and titratable acids. Importance was attached to the rate of change in soluble solids during delayed harvest and to the rate of degradation of soluble solids and titratable acids during storage.

MATERIALS AND METHODS

Samples of apples of each of the cultivars 'Gravenstein', 'Summerred', 'Aroma' and 'Karin Schneider' ('Red Ingrid Marie') were picked during five consecutive weeks, covering the commercial harvest season of each of these cultivars in the region (Table 1). The apples were grown in the experimental field at Ullensvang Research Station, Lofthus, Western Norway, latitude 60°N. The experiment covered the years 1986-88. The fruit was stored in refrigerated storage rooms at approximately 4°C ('Gravenstein' and 'Summerred') and approximately 2°C ('Aroma' and 'Karin Schneider'), in order to simulate the conditions under which these cultivars are usually stored at packhouses in the region.

Table 1. (a) first harvest dates, (b) first dates of quality analyses during storage and (c) number of quality evaluations during the storage season for four cultivars and three years

	1986			1987			1988		
Cultivar	a	b	c	a	b	c	a	b	c
Gravenstein	09.04	10.16	5	09.02	10.14	5	08.22	10.03	4
Summerred	09.10	10.22	4	09.07	10.19	4	08.30	10.11	3
Aroma	09.23	11.04	6	09.22	11.03	5	09.14	10.26	5
Karin Schneider	09.29	11.10	5	10.01	11.12	5	09.22	11.03	5

Soluble solids and titratable acids in fruit samples containing 10 apples each (three replicates) were measured both at harvest (one week intervals) and during the storage season (four-week intervals). The apples were kept at room temperature for one day ahead of the analyses to simulate a short shelf-life period. The starting dates of the experiments for each year and for each cultivar are given in Table 1. Because of differences in storage quality, the number of analyses during the storage season varied between cultivars as well as seasons (Table 1).

Soluble solids were measured by an ATAGO DBX - 50 digital refractometer. Titratable acids were determined by titrating diluted juice samples to pH 8.1 with 0.01 N NaOH.

RESULTS AND DISCUSSION

Content of soluble solids

During the harvest season, delayed picking increased the soluble solids of the fruit (Fig. 1). The increase was found to be approximately linear in all cultivars and years, with slopes ranging from 0.23 to 0.69 when weeks were used as the independent variable (horizontal axis), not unlike the pattern found by Vestrheim (1970). This increase is important and should be taken into account especially when a low content of soluble solids is found at the beginning of the picking period.

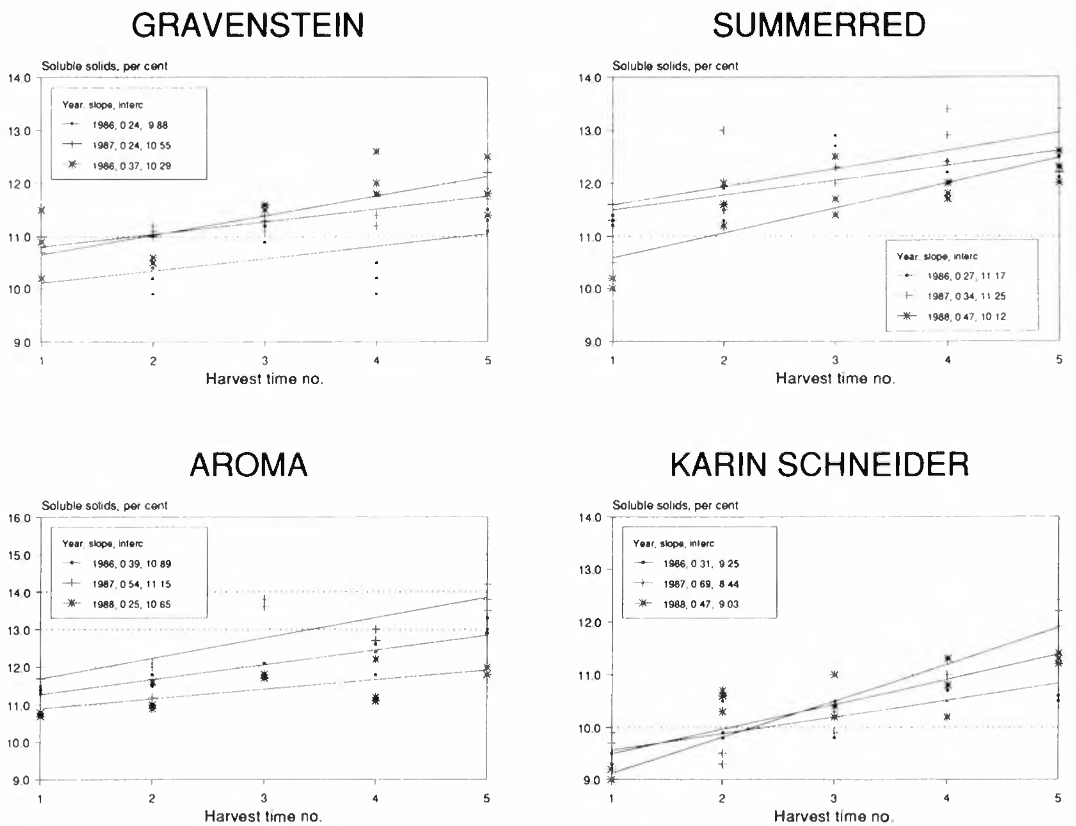

Fig. 1. Changes in the content of soluble solids expressed as regression lines during the harvest period of four cultivars and three years

During storage, the changes in soluble solids followed different patterns for both cultivars and for years. The two earliest ripening cultivars 'Gravenstein' and 'Summerred' showed a decline in soluble solids during the storage season fitting more or less well to a straight line (Table 2). The magnitude of the slope indicated that in most cases approximately 0.25-0.50 % of soluble solids were lost during every four-week storage period under the storage conditions used.

Table 2. Changes in the content of soluble solids during the storage period expressed as an approximation to a regression line for two cultivars and three years

		Gravenstein			Summerred		
Year	Harvest time no.	Slope	Intercept	Corr.-coeff.[1]	Slope	Intercept	Corr.-coeff.[1]
1986	1	-0.33	11.57	-0.72**	-0.46	12.68	-0.62*
	2	-0.58	12.20	-0.76**	-0.23	12.30	-0.72**
	3	-0.41	12.06	-0.86**	-0.37	12.70	-0.91**
	4	-0.29	11.59	-0.65**	-0.45	13.28	-0.89**
	5	-0.36	11.91	-0.76**	-0.31	12.87	-0.85**
1987	1	-0.22	11.68	-0.52*	-0.28	12.80	-0.55
	2	-0.36	12.26	-0.87**	-0.38	12.53	-0.59*
	3	-0.36	12.22	-0.92**	-0.47	13.58	-0.59*
	4	-0.40	12.42	-0.92**	-0.39	13.68	-0.79**
	5	-0.36	12.12	-0.86**	-0.22	12.67	-0.56
1988	1	-0.69	13.03	-0.91**	-0.33	11.92	-0.61
	2	-0.37	11.93	-0.80**	-0.37	11.76	-0.69*
	3	-0.42	12.77	-0.72**	-0.15	11.73	-0.36
	4	-0.43	12.32	-0.88**	-0.15	11.69	-0.27
	5	-0.47	13.49	-0.88**	-0.20	12.04	-0.38

[1]: *: $p \leq 0.05$, **: $p \leq 0.01$

For 'Aroma' and 'Karin Schneider', curvilinear and less systematic changes in soluble solids were obtained, often without any type of pattern being repeated. It was obvious that there was an increase in soluble solids of the later ripening cultivars during the first part of the storage period, followed by a reduction, as shown in Fig. 2. This is most likely due to the conversion of starch and other carbohydrates into sugars reflecting higher refractometric readings in the period after harvest.

Apples from the first picking time remained lowest in soluble solids throughout the storage period, as indicated in Fig. 2. This is probably due to a shorter growing season and a less plentiful supply of carbohydrates, but the longer storage period compared with apples picked later should also be taken into consideration.

The reduction in soluble solids during storage constitutes a degradation of the fruit quality and this should be taken into account when determining the termination of the storage period for apples of satisfactory eating quality. This is especially critical for apples that are low in soluble solids at harvest.

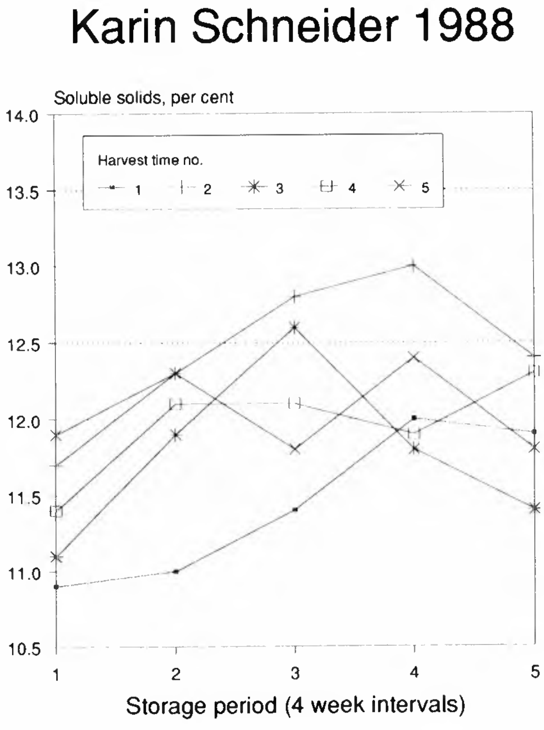

Fig. 2. Changes in the content of soluble solids of apples harvested during five consecutive weeks of cv. 'Karin Schneider' during storage 1988

Content of titratable acids
The content of titratable acids also changed during the harvest season, forming different patterns. Usually the acids declined throughout the picking season, but examples were found where a maximum was reached at the middle harvest time, followed by a decline.

During storage the content of titratable acids declined more or less systematically in all cultivars and years with one exception; 'Gravenstein' in 1987, where no systematic decline was found. The decline followed a different pattern for both cultivars and years. Often there was a clear linear decline (see Fig. 3) for most of the cultivars. Logarithmic patterns, like those reported by Fidler (1951) and Landfald (1968), were typically found in 'Aroma' apples in 1986. Similar trends were also found in the other cultivars. This type of decline in acids during storage is logical because of the lower concentration of acids following storage and thereby a reduction in the acid losses. A logarithmic pattern would more than likely be found in all cases if the apples were monitored during an extended storage season.

In 'Gravenstein' and 'Summerred' the acid content of the first-picked apples remained highest during the storage season. Similar patterns were obtained by Vestrheim (1971). In 'Aroma' and 'Karin Schneider' no such variations in acids during the storage season caused by differences in harvest time were obtained (Fig. 3). This is in contradiction with the results published by Vestrheim (1971).

The pronounced differences in the magnitude of the slopes should be noticed (Fig. 3); 'Summerred' displayed the strongest decline in acid content during storage, followed by 'Karin Schneider' and 'Aroma'. 'Gravenstein' showed the smallest rate of decline. Similar results were published by Vestrheim (1971), and he concluded that cultivars

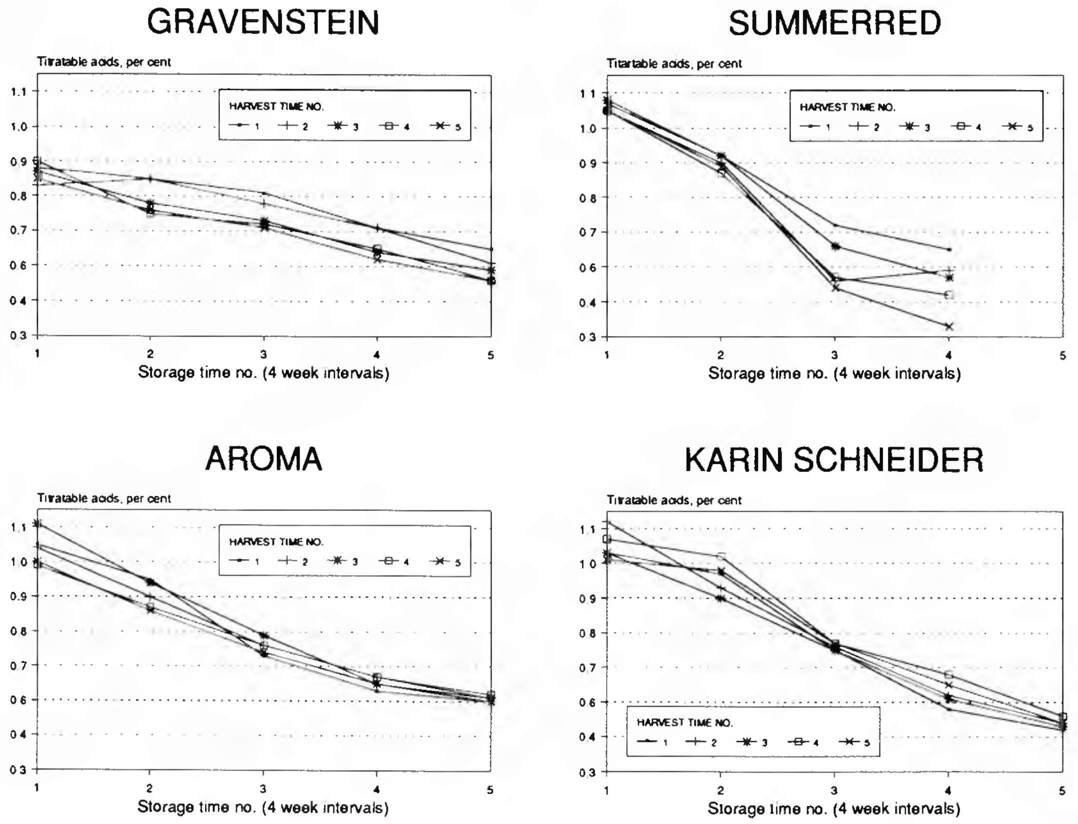

Fig. 3. Changes in the content of titratable acids during storage in apples of four cultivars harvested during five consecutive weeks in 1986

with the highest content of acids at harvest will have the fastest reduction of acids during storage.

Since the acid content is of vital importance to the taste quality of apples, the titratable acids should be taken into account when decisions are made on when to terminate the storage season.

The soluble solid:titratable acid ratio

The increase in the soluble solid:titratable acid ratio during the harvest period were found to be a marked linear one for all the cultivars and years; slopes varying between 0.31 and 1.21 and correlation coefficients between 0.779 and 0.941, all being significant at the 1 % level. Interestingly enough, this ratio, for all cultivars and years, was well below the value of acceptance threshold (16) proposed by Vangdal (1985) during the five weeks of harvest. Only 'Gravenstein' approximated this value at the latest harvest dates each year.

During storage, the increase in the soluble solid:titratable acid ratio continued in all cultivars (Fig. 4). with the exception of cv. 'Gravenstein', where an increase similar to that found in the other cultivars was obtained in 1986 only. In 'Gravenstein' and

'Summerred' the first-picked apples remained lowest in soluble solid:acid ratio throughout the storage period, but this trend was either missing or less clear-cut in the other two cultivars. It should be pointed out that usually the apples had to be stored for a period before the threshold value introduced by Vangdal (1985) was reached. 'Gravenstein' apples picked early in the harvest season never reached this value, revealing an unsatisfactory eating quality.

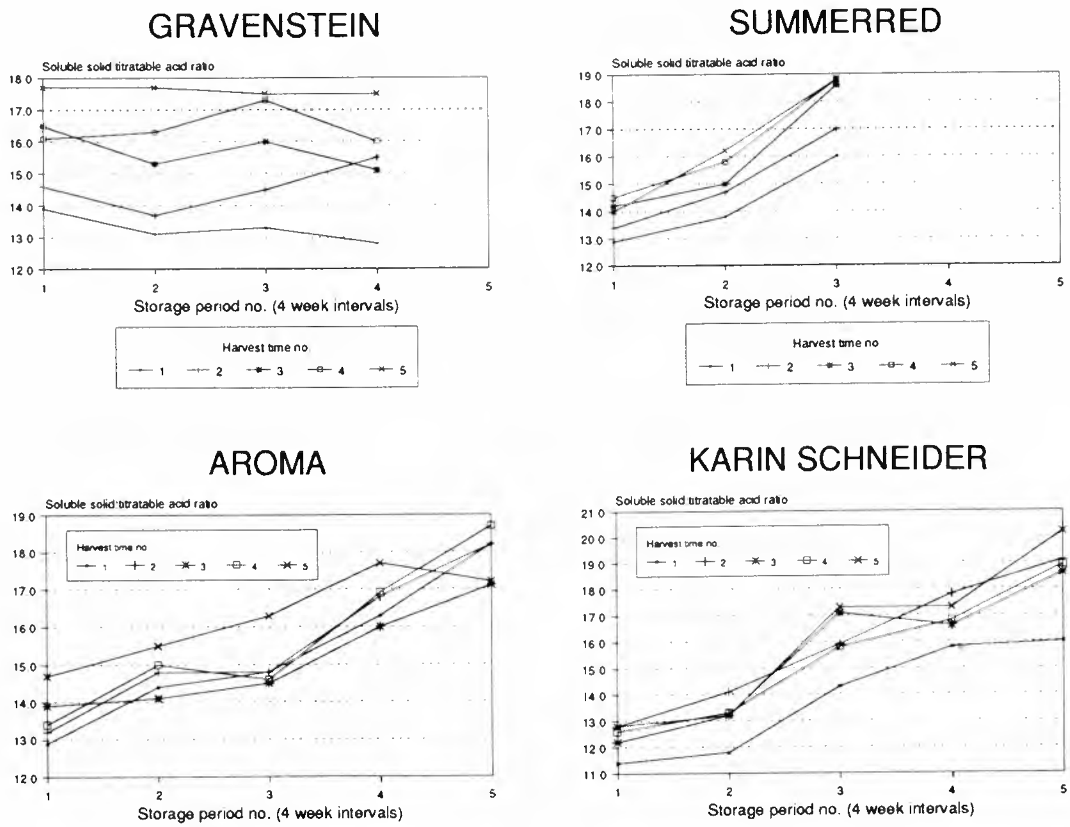

Fig. 4. Changes in the soluble solid:titratable acid ratio during storage of apples of four cultivars harvested during five consecutive weeks in 1988

SUMMARY

During an actual apple harvest period changes occur in content of soluble solids and also in content of titratable acids and their ratio; the soluble solids and the soluble solid:titratable acid ratio increase, but titratable acids decrease. Since the content of soluble solids is regarded as the most important quality factor of Norwegian-grown apples, the benefits of a delayed harvest with regard to soluble solids should be taken into account when deciding on when to harvest. The decrease in titratable acids during

this same period is probably also beneficial to the total fruit quality of most apple cultivars.

During storage, there is a decrease in both soluble solids and titratable acids, but the ratio of the two parameters increases with few exceptions. The decrease both in soluble solids and in titratable acids during storage represents a quality loss. In particular, the rapid decrease in acids during storage which is found in some of the cultivars that are naturally high in acids at harvest is important and should be assessed in determining the termination of the storage season.

It should be noted that most of the cultivars tested needed to be stored for at least some weeks before a sufficiently high soluble solid:titratable acid ratio was reached to ensure a satisfactory eating quality.

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Orchard soil management systems. Effects on growth and fertility of apple trees

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In a study of orchard soil management seven different systems including grass ley, herbicidal and mechanical weed management, and bark and three different artificial mulches were tested. The grass ley system was found to be inferior to the other systems in growth, fertility and fruit size. Vegetative growth was most vigorous in mulched trees, and somewhat less so in the open soil treatments. Apart from in the grass ley system, average yields were not significantly affected by soil management. Yield stability, however, was markedly reduced in bark-mulched (and grass ley) trees, and highest in open soil treatments. Excluding grass leys, fruit size and internal and external fruit quality parameters were not significantly affected by soil management.

Key words: Apple, biennialism, flowering, fruit quality, growth, mulching, soil management, yield, yield efficiency

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The influence of different soil management systems in temperate orchards has been studied many times since early this century. One of the first effects to be observed was the inefficiency of cover crops to clean soil cultivation or organic mulching systems (Fagan et al. 1933; Hedrick 1914; Woodbury et al. 1917). As herbicides became available, tests showed that a weed-free strip along the tree row could fully replace clean cultivation (Baxter 1970; Mellenthin et al. 1966; White & Holloway 1967), but could not keep up with organic mulch either in tree growth or in yield. Recently synthetic mulches have been shown to have a marked effect on establishment and performance of young fruit trees (Funke 1982; Husabø 1975; Jonkers & Borsboom 1981; Måge 1982; Stojanovska 1987).

The reason for the inefficiency of cover crop systems appears to be that interplant competition depletes the fruit trees of both mineral nutrients and water. Drastically reduced moisture levels under a grass ley compared to clean cultivation were found in a Danish study (Rasmussen 1958), and similar results have been observed in studies from Australia (Baxter 1970) and Norway (Måge 1982). Among the mineral nutrients, nitrogen seems to be the one most affected by a cover crop. Both Baker (1936) and Ljones (1958) found very low nitrate levels under grass leys compared to cultivated soil, and large amounts of applied nitrate were needed to restore growth of trees in grass leys

(Ljones 1958). Effects on other minerals have been less carefully studied, but leaf analyses indicated less potassium availability under a grass sward related to clean soil treatments (Måge 1982). Leaf P and Mg, on the other hand, were higher in leaves from trees in grass leys than from corresponding clean soil plots. Ample nitrogen availability, soil erosion problems or low soil humus content may, however, render clean soil systems unfavourable to cover crop systems (Baker 1936; Rogers & Raptopoulos 1946).

The advantages of mulching over clean soil systems appear to be the physical effects of mulching upon the soil environment (Tukey & Schoff 1963). The effect on water conservation has been clearly demonstrated by several workers (Ashworth & Harrison 1983; Baxter 1970; Liptay & Tiessin 1970; Måge 1982; Rasmussen 1958). Increases in nitrogen (N) appear to be a general effect of mulching irrespective of mulch material, whereas the effects on other mineral elements are less clear-cut (Funke 1982; Måge 1982; Niggli et al. 1989; Shribbs & Shrock 1986; White & Holloway 1986).

As pointed out by Tukey & Schoff (1963) mulches can be expected to affect soil physics in a rather similar way. However, synthetic thin layer mulches differ principally from most other mulch materials in their effects on soil temperature. Whereas without exception organic and bulky inorganic mulches lower the growing season soil temperature (Ashworth & Harrison 1983; Hill et al. 1982; Niggli et al. 1989; Tukey & Schoff 1963), the opposite is true for most synthetic filmy mulches (Funke 1982; Hill et al. 1982; Måge 1982; Waggoner et al.1960). Exceptions are reflecting films, which tend to cool the soil compared to non-covered plots (Hill et al. 1982). Tromp (1984) found a linear increase in vegetative growth of apple trees with increasing root temperature up to 30°C, whereas flower bud formation showed an optimum at approximately 18°C. Thus, differences in soil temperature may possibly explain the superiority of plastic over organic mulch in both vegetative growth and flower bud formation (Jonkers & Borsboom1981), and may also explain the particularly pronounced effects of black plastic mulches under Norwegian conditions, where the growing season temperature is the main limiting factor to economical fruit growing (Husabø 1975; Måge 1982).

MATERIALS AND METHODS

Plant material and field establisment

Graftings of Aroma on MM106 were made in spring 1980. The trees were raised in an unheated greenhouse during the first growing season, and then outdoors in a nursery field for the summer of 1981. Growth was minimal during the latter season.

One hundred and twelve trees were selected for uniformity and planted in the experimental field in spring 1982. Upon planting, all laterals were removed, and the trees were pruned back to uniform height (65 cm). During the winter of 1982-83, the newly formed laterals of the 1982 season suffered severe damage from marauding wild hares. To re-establish maximum uniformity among the young trees, all laterals were removed in spring 1983 as well.

Apart from tipping and removal of one or more competing leaders, pruning in spring 1984 was kept to a minimum. In the subsequent years the trees were pruned as much as necessary in order to obtain a manageable free spindle type of crown.

Experimental design

The experimental plot was divided into eight blocks each comprising seven different soil management systems, and was arranged in two rows on a southwest bound slope in the experimental orchard at the Department of Horticulture of the Norwegian Agricultural University. Each treatment covered an area of 4.0 x 1.2 m^2, and was planted with two trees 1.5 m apart. Distance to the nearest tree of the neighbouring treatment was 2.5 m, and row distance 5 m.

The seven soil management systems were applied in the tree rows only, whereas the area between the rows was covered by a 3.5-4 m wide, regularly mown grass sward. The seven different treatments were as follows:

1. Mechanical cultivation. The soil was hand-hoed when required in order to prevent weed establishment.
2. Grass ley. The grass sward was established on 21 June 1982, and mown three or four times per season the following years.
3. Bark mulch. A 10-15 cm layer of pine bark was spread under the trees on 2 July 1982.
4. Herbicidal weed management. Various herbicides including both anti-germinators and systemic herbicides for foliar application were used when required.
5. Black plastic film, 1 mm. The foil was laid on 29 June 1982, and partly renewed in 1984. In 1988 all plots were renewed.
6. Black plastic web (MyPex, Amoco). Laid on 2 July 1982, and renewed when required. In 1988 all plots were renewed.
7. Black roofing felt (Icopal). Laid on 24 June 1982.

Recording and statistical analysis

Vegetative growth was recorded as yearly trunk circumference mensurations during the dormant period. For the first two years in field (1982 and 1983) the number of shoots longer than 10 cm and the length of the five longest shoots on each tree were recorded, the latter also in 1984. Weight of prunings was recorded in spring 1987, 1988 and 1989.

Flowering was recorded as flower clusters per tree in 1985 and 1986, whereas in 1987 and 1990 flower intensity was recorded as points on an arbitrary scale ranging from 0 to 5 (5 being maximum flowering). Fruit set was calculated from fruits per tree at harvest in 1985 and from fruitlets per tree on 5 July in 1986. Average fruit size was estimated based on 50 randomly chosen fruits per plot (= two trees).

Fruit quality parameters were fruit colouring, soluble solids and titratable acids. Both ground colour (degree of yellowing) and amount of red surface were recorded by several persons using an arbitrary scale ranging from 0 to 9 (9 being maximum development of yellow or red), and the means were used for statistical calculations. Soluble solids as an estimate of sugar content was determined on apple juice after filtering using an Abba table refractometer. Titratable acid content was determined by adjusting 10 ml juice to pH 8.1 with 0.1 N NaOH, and multiplying the amount of lye consumed (ml) by a factor of 0.067, yielding acidity as percent malic acid equivalents.

Statistical analyses were carried out on a computer using the MSTAT data analysis system (Nissen & Mosleth 1985). Regular F-tests were applied to orthogonal or nearly orthogonal data sets (missing values were estimated manually at a price of one degree of freedom per estimate). Non-orthogonal data were tested for significance by subroutine «Utjevn», applying the method of least square means.

RESULTS

Distinct differences in tree growth were found between the various soil management systems. Expressed in terms of trunk circumference, trees growing in soil covered with either bark, continuous plastic or roofing felt were during most of the period about 50% larger than trees growing in the grass leys (Table 1). The trees of the remaining treatments were approximately 10% smaller than the most fast growing ones. The differences were established already after two growing seasons, and remained more or less the same in the following years. However, by the end of the experimental period the relative yearly increase in trunk circumference was somewhat more for trees in grass leys than for the previously more fast-growing ones. Among the non-cover crop systems, the trees in mechanically cultivated soil had significantly smaller trunk circumferences than the trees from the remaining systems.

Table 1. Trunk circumferences (mm) of trees under different soil management regimes 1982-90

Treatment	1982	1983	1984	1985	1986	1988	1990
1. Mechanical cultivation	34	62	97	139	162	221	258
2. Grass ley	33	41	64	84	108	168	216
3. Bark mulch	35	69	113	158	190	253	293
4. Herbicidal weed control	36	64	102	142	169	232	274
5. Plastic film	37	73	115	156	182	244	289
6. Plastic web	37	67	108	147	174	234	274
7. Roofing felt	38	74	115	152	179	233	271
Average	36	64	102	140	166	226	268

The variation in annual shoot growth was as pronounced as the variation in trunk circumference (Table 2). Young trees growing in bark mulch seemed to have the most marked shoot elongation, followed by those growing under the plastic coverages, roofing felt and herbicide treatment, whereas those under mechanical cultivation lagged somewhat behind. However, the most marked difference in this respect, too, was the gap between shoot growth on trees in the grass leys and the other treatments.

Table 2. Vegetative growth. A. Number of shoots > 10 cm per tree (average of 1982 and 1983). B. Length (cm) of the five longest shoots per tree (average 1982-84)

Treatment	A. Shoot number	B. Shoot length
1. Mechanical cultivation	11.6	52.0
2. Grass ley	8.9	35.1
3. Bark mulch	11.7	63.3
4. Herbicidal weed control	10.8	57.1
5. Plastic film	11.9	60.7
6. Plastic web	11.8	56.9
7. Roofing felt	12.4	63.2
Average	11.3	55.5
Treatment: LSD(0.05) =	2.3	7.3

The first flowers appeared and the first fruits set in spring 1984. However, neither the trees in grass leys nor those in bark mulch bloomed until the following spring. Over a period of six years, trees established in plastic film produced an average of 14.2 kg apples per tree and year (Table 3), whereas trees in the grass leys produced only about 40% of that amount. The remaining systems displayed yield levels around or somewhat above the field average of 11.7 kg per tree and year.

Table 3. Apple yield (kg per tree) from trees under different soil management regimes 1984-89

Treatment	1984	1985	1986	1987	1988	1989	Average
1. Mechanical cultivation	1.13	2.19	7.19	18.25	11.06	26.63	11.07
2. Grass ley	0.0	0.56	1.81	14.06	1.81	16.44	5.78
3. Bark mulch	0.0	4.75	3.56	29.94	8.75	32.38	13.23
4. Herbicidal weed control	0.56	2.56	6.69	18.06	11.00	29.31	11.36
5. Plastic film	1.13	7.69	7.75	28.50	11.44	28.94	14.24
6. Plastic web	0.88	4.94	7.44	24.88	9.63	31.25	13.17
7. Roofing felt	0.56	6.50	6.63	26.94	7.50	28.38	12.75
Average	0.61	4.17	5.87	22.95	8.74	27.62	11.66

Treatment : LSD(0.05) = 4.12
Year : LSD(0.05) = 4.52

Calculations of yield efficiency, expressed as yield per cm trunk circumference, revealed considerable differences among the various soil management systems used (Table 4), with the most marked differences in the earlier years. Averaged over six years, yield efficiency varied between the 0.36 kg apples per cm trunk circumference of the trees in grass leys and 0.66 kg apples per cm trunk circumference of trees in plastic film. The remaining treatments varied between 0.55 and 0.61 kg/cm. It should be noted, however, that among these, yield efficiency of trees in bark mulch was in most years considerably lower than that of the other treatments.

Table 4. Yield efficiency; i.e. yield (kg) per cm trunk circumference

Treatment	1984	1985	1986	1987[1)]	1988	1989[1)]	Average
1. Mechanical cultivation	0.13	0.16	0.47	0.94	0.51	1.09	0.55
2. Grass ley	0.0	0.06	0.16	0.99	0.10	0.83	0.36
3. Bark mulch	0.0	0.30	0.19	1.35	0.34	1.18	0.56
4. Herbicidal weed control	0.06	0.19	0.41	0.89	0.47	1.12	0.52
5. Plastic film	0.10	0.51	0.45	1.34	0.48	1.08	0.66
6. Plastic web	0.08	0.33	0.43	1.22	0.41	1.22	0.61
7. Roofing felt	0.05	0.44	0.36	1.31	0.37	1.11	0.60
Average	0.06	0.28	0.35	1.15	0.38	1.09	0.55

[1)] Calculated from stipulated trunk circumferences
Treatment: LSD (0.05) = 0.31
Year: LSD (0.05) = 0.36

In order to evaluate yield stability of trees under various regimes of soil management, a method proposed by Ljones (1951) was applied. Briefly this method involves comparison of obtained yields to a regression curve calculated between years of bearing and yield in each year. In Figure 1 the regression curve is set to 100, and the actual yield values are plotted relative to this. As can be seen from the figure, the open soil systems appear to give the most stable yield, whereas the most extreme fluctuations were found in the grass leys and, slightly less so, in the bark mulch. The remaining system occupied a somewhat more intermediate, though relatively distinct, pattern with respect to biennialism.

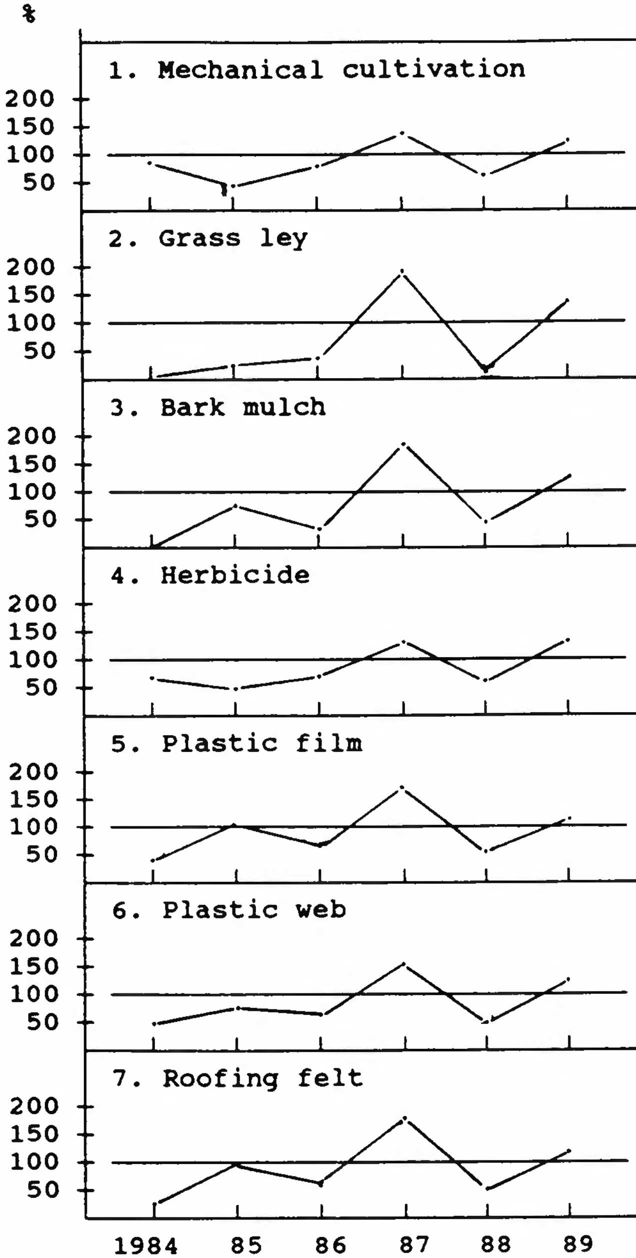
The intensity of flowering differed considerably during the early years after planting, whereas the variation seemed to level out in later years (Table 5). In two of the four years the flower record of trees in grass ley were the lowest, not amounting to more than 20-40% of the average. However, in 1987 these trees were the highest in bloom density, and in 1990 they were not significantly different from the field average. Trees in plastic film, plastic web or roofing felt had relatively high scores in three of four years, whereas the open soil treatments were either around or below the field average.

Table 5. Flowering. 1985 and 1986: a = Flower clusters per tree. b = Flower clusters per cm trunk circumference. 1987 and 1990: Flower density as noted on an arbitrary scale from 0 to 5 (max)

Treatment	1985		1986		Average				
	a	b	a	b	a	b	1987	1990	Average
1. Mechanical cultivation	23.4	1.7	62.0	3.9	42.7	2.8	3.4	2.8	3.1
2. Grass ley	10.8	1.2	20.3	1.9	15.5	1.6	4.6	2.3	3.4
3. Bark mulch	47.0	3.0	33.1	1.7	40.1	2.4	3.9	2.2	3.0
4. Herbicidal weed control	23.6	1.7	54.0	3.2	38.8	2.5	3.1	2.5	2.8
5. Plastic film	82.0	5.3	56.0	3.2	69.0	4.2	4.0	2.0	3.0
6. Plastic web	54.5	3.7	61.9	3.5	58.2	3.6	3.7	2.6	3.1
7. Roofing felt	62.4	4.2	49.6	2.7	56.0	3.5	4.1	2.4	3.3
Average	43.4	3.0	48.1	2.9	45.8	2.9	3.8	2.4	3.1
Treatment: LSD(0.05) =					24.9	1.4			N.S.

Fruit set was only calculated for 1985 and 1986. Also in this respect trees in grass leys displayed considerably lower values than those in any of the other systems, whereas only insignificant differences were found among the latter.

Fruit quality factors were significantly affected by season, but were, with a few exceptions, only slightly influenced by soil management. Trees in grass leys produced fruits that were about 20% smaller than average, whereas only minor differences were found among the other treatments (Table 6). Fruits of grass ley trees also carried more red colour than most other treatments. However, no significant differences were found among the soil management systems with respect to ground colour, or content of soluble solids and fruit acids (Table 6).



	r	a	b
1. Mechanical cultivation	0.900	7.05	4.14
2. Grass ley	0.721	- 4.54	2.37
3. Bark mulch	0.777	- 8.64	4.99
4. Herbicide	0.892	- 8.02	4.44
5. Plastic film	0.827	- 6.11	4.58
6. Plastic web	0.837	- 7.45	4.68
7. Roofing felt	0.785	- 6.14	4.27

Fig. 1. Degree of biennialism in the soil management systems. The figure shows actual yield related to values calculated from a linear regression between years (1983-89) and average yield of each treatment. Regression curve = 100%. r = regression coefficient; a,b = regression constants (y = ax + b)

Table 6. Fruit quality parameters. A: Fruit size (g) (Average of 1985 and 1987-89). B,C: Ground and red colour recorded on an arbitrary scale from 0 to 9 (Average of 1986-88). D,E: Soluble solids (%) and malic acid equivalents (%) (Average of 1985-1988)

Treatment	A. Fruit size	B. Ground colour	C. Red colour	D. Soluble solids	E Malic acid equiv.
1. Mechanical cultivation	139.3	6.7	3.7	13.4	0.81
2. Grass ley	117.8	7.0	4.3	13.0	0.78
3. Bark mulch	140.1	6.6	3.5	13.1	0.81
4. Herbicidal weed control	144.7	6.9	3.5	13.1	0.79
5. Plastic film	144.0	6.8	3.6	13.0	0.79
6. Plastic web	137.1	7.0	3.5	13.3	0.80
7. Roofing felt	137.8	6.5	3.4	13.2	0.80
Average	137.5	6.8	3.6	13.2	0.80
Treatment: LSD (0.05) =	20.0	N.S.	0.9	N.S.	N.S.

DISCUSSION

Physiological aspects

For vegetative growth, the main difference was found between the grass ley and the other systems. The negative effects of a permanent grass sward on growth are well known (Hedrick 1914; Rogers & Raptopoulos 1945) and are most likely accounted for by competiton for water and mineral nutrients (Ljones 1958). An additional cause may be allelopathic effects from the grass roots (Salisbury & Ross 1985). Compensatory fertilizer applications might also have reduced the growth inihibition.

Given the relatively marked effects of root temperature on vegetative growth in apple trees demonstrated by Tromp (1984), the differences among the remaining systems are surprisingly small, in particular as the two extremes on the temperature range (Ashworth & Harrison 1983, Skogerbø 1991), the bark and the plastic mulch, are nearly identical in vegetative growth. Higher yields and more rapid exploitation of soil resources may have led to earlier growth cessation, thus inhibiting trees in plastic mulch from utilizing their higher growth potential.

The slightly weaker growth found in the open soil systems and in the plastic web mulch is probably accounted for by evaporative loss of water from the soil, with evaporative cooling perhaps being a contributory factor.

For flowering and yield, the greatest differences were still found between the grass ley and the other systems, particularly in the early years. The low flower bud formation in trees in grass leys versus the other systems is not easily accounted for. Reduced water availability is normally associated with increased flowering (Degman et al. 1932; Nyhlén 1986), whereas the opposite is true for phosphorus availability (Bould & Parfitt 1973; Taylor 1975). As for nitrogen, it seems that low availability in spring may enhance flowering (Hill-Cottingham & Williams 1967), whereas continuously low levels of N may be equally damaging as a concentrated spring application (Delap 1967).

Among the more equally sized trees, the general impression from the field was - although not too well reflected in the tables - that trees in bark and plastic film mulch were equal in vegetative growth, but rather dissimilar in generative development. The bark-mulched trees did not come into bloom until one year after the plastic-mulched ones, and did not enter the same level of blooming until 1987. Differences in root temperature (Tromp 1984), perhaps mediated through the cytokinin levels (Hoad 1984), offer one possible explanation. However, differences in growth habit may also be part of the reason, as delayed shoot growth cessation of the bark mulched trees may have left most buds at the vegetative stage upon entering the dormant condition.

The remaining systems occupied intermediate positions with respect to flowering as they did in vegetative growth. Explained in terms of root temperatures, both open soil and plastic web systems would lose heat by evaporative cooling, whereas the brighter and somewhat reflecting surface of the roofing felt might reduce heating from radiation to some extent. However, temperatures measured under roofing felt were on average higher than in any of the other treatments (Skogerbø & Måge 1992).

Fruit set displayed little variation apart from the low level of trees in the grass leys, which most likely was a result of low moisture and nitrogen resources. The differences in yield efficiency probably reflect the effects of grass ley on both flowering and fruit set, whereas low flowering only can account for the intermediate value of the bark mulch.

According to Ljones (1951) alternate bearing is normally triggered by an off-year, indicating that adverse conditions play a greater role in inducing biennialism than do fertility-stimulating factors. In this context the susceptibility to biennialism displayed by the grass ley and the bark mulch systems may be a direct result of the lower fertility potential of trees in these systems, which renders them more sensitive to the effects of factors reducing fertility. In the case of grass leys both flower bud formation and fruit set are hampered, producing the most marked alternations in yield. In bark mulch, fruit set is apparently not affected, whereas the flowering ability is strongly reduced. In 1984 flowering was nil, which may explain the relatively high score in 1985. Fruit load in 1985 was only moderate, nevertheless inducing the lowest flower bud efficiency that year. Thus the factor inducing biennialism in bark mulch is most likely the same as that hampering flower bud formation.

The reasons for the difference in yield fluctuations found between open soil and synthetic mulch systems are less obvious. The somewhat lower flowering efficiency of the open soil systems may render these less inclined to «over-bloom» and «over-yielding» without totally preventing flower bud formation in any year. Combined with a normally high setting ability this may dampen the fluctuations seen in the more extreme systems (i.e. plastic film and bark mulch). A «softer» start to the bearing period may also have been a contributory factor.

Practical aspects

By process of elimination, the results leave no doubt as to which soil management system should be the first to be discarded for modern orcharding. The grass ley system as practised in this trial was inferior to the other systems in all respects; tree establishment and growth, earliness of yield, yield capacity and efficiency, regularity of fruiting and fruit size. Fruit colour was the only character that was positively affected.

Turning to the remaining soil management systems, the choice of system will depend on costs and benefits. As fruit quality is virtually unaffected by soil management, yield capacity and regularity will be the deciding factors on the credit side. Accumulated yields after six cropping years were not significantly different, indicating that differences over an orchard life time will not be very clear-cut. Yet, the mulch system display somewhat higher yields than the open soil ones, a difference that, if verified, may compensate for the possibly higher cost of a mulch system. Early yield differences are pronounced and may be decisive in whether bark or synthetic mulch should be used for orchard establishment.

On the debit side, herbicides, mulching materials and labour will be the main entries. Labour costs are likely to be the most important, rendering, if not mechanizable, mechanical cultivation of the tree row strip unattainable. Application of synthetic mulches is also laborious, particularly if frequent renewal is required. Fresh bark mulch is relatively easily applied and has a long effective lifetime (6-8 years), and may thus possibly compete with a herbicidal regime on the labour cost scale. Among the mulching materials bark is probably the cheapest and roofing felt the most expensive; the latter, however, compensating somewhat for the cost by having a very long efficient lifetime.

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Seed production in onions (*Allium Cepa* L.) with special reference to seed yield and quality

a) Influence of plant density and size of spring transplanted mother bulbs on seed yield and quality

b) Influence of different systems of seed production on seed yield and quality

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Vik, J. 1992. Seed production in onions (*Allium Cepa* L.) with special reference to seed yield and quality. a) Influence of plant density and size of spring transplanted mother bulbs on seed yield and quality. b) Influence of different systems of seed production on seed yield and quality. Norwegian Journal of Agricultural Sciences 6: 133-143. ISSN 0801-5341.

Experiments in seed growing in Allium Cepa, with the plant factors distance and size of mother bulb, were carried out in unheated greenhouses of plastic and glass at Toten and Grimstad in 1988 and 1989. Three different distances between the mother bulbs were included.
During the season 1988/1989 experiments with different seed production methods in *Allium cepa* L. were carried out at Landvik Research Station. The seed-to-seed method was compared with that of transplanting full grown mother bulbs (150-200 g) in autumn and spring.

Key words: Bulb size, growing techniques, onion, plant density, seed growing

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a) Influence of plant density and size of spring transplanted mother bulbs on seed yield and quality

Seed production of onions in Norway has to be performed in unheated glass- or plastic houses. This is an expensive growing technique, and therefore it is vital to obtain a high seed yield of good quality.

Many experiments (Jones & Elmsweller 1939; Singh et al. 1974; Rusev 1978; Tudzarov 1982), however, emphasize both size of the mother bulbs and plant density (distance between seed plants) as very important factors in this respect. Each of these factors has been investigated but not in combination, and all experiments have been performed in the open. The experiments point out neither the most adequate size of mother bulb nor plant density.

The aim of this study was to find the best combination of bulb size and plant density for giving the highest seed yield and quality.

MATERIALS AND METHODS

Three experiments were carried out, two in the district of Grimstad and one in the district of Toten, in 1988 and 1989.Four sizes of motherbulbs were included: 60-80, 80-100, 100- 150 and 150-200 g, and three plant densities: 36, 18 and 12 plants per m^2 or space per plant in the bed 200, 400 and 600 cm^2. The plants in each row were spaced 10, 20 and 30 cm apart, with 20 cm between rows (5 rows) and 60 cm between beds. The experimental plots were 1.4 to 2.1 m^2 in areal and with three replicates per treatment. Bees were the pollinating insect. The transplanting, flowering, harvesting and germination test dates for the two districts and three varieties tried were as follows:

Districts, years of performance	Trans-planting	Flowering	Harvesting	Germination	Names of varieties
Toten - 1988	25-26/4	2/7-2/8	28/9-20/10	20/11-12/12	Laskala
Grimstad - 1988	5- 6/4	15/6-1/8	16/8-21/ 8	23/11- 7/12	Lafort
Grimstad - 1989	23/3	17/6-5/7	15/8-25/ 8	27711-10/12	Laskala

The seeds were harvested three and four times when the seeds were dark, umbels brown with and without open capsules, and with a 10-15 cm stem length. Drying, threshing and cleaning were done in the usual way. The observations were: Yield per umbel, per plant and per areal unit, weight of 1000 seeds and germination percentage for normal and abnormal seedlings, ungerminated and dead seeds. The analysis of variance included the size of the mother bulb, plant density, place and year of performance, and the interaction between these factors. The levels of significance are indicated by * ($P=0.05$), ** ($P=0.01$) and ***($P=0.001$).

RESULTS

The analysis of variance proved that there were significant differences between plant densities and sizes of mother bulbs in all characters observed, with the exception of weight of seed and germination percentage. Furthermore, there was no interaction between these factors in any of the characters. On the contrary, there were significant differences between these factors and plant densities. However, since this interaction had the same trend in all experiments, these variations are added to the fault. The presented data of variance are therefore only related to the main effect.

Size of the mother bulb
The yield per umbel was slightly decreased with increasing sizes of mother bulbs, from 3.6 to 3.2 g. (Table 1). Number of umbels per plant, however, was considerably increased from the smallest (60-80 g) to the biggest (150-200 g) mother bulbs, from 2.2 to 3.3. Consequently the yield of seed per plant and per 100 m^2 was markedly increased by a gradual increase in size of mother bulb. From the smallest to the biggest mother bulb

the seed yield per plant increased from 7.8 to 10.4 g, and per 100 m^2 from 16.6 to 21.7 kg. The greatest difference in yield was found to be the mean of the mother bulbs under and over 100 g. The difference between the two biggest and the two smallest sizes tried, seemed to be less remarkable.

Table 1. The influence of size of the mother bulb on number of umbels per plant, g seed per umbel and per plant, and seed yield (kg per 100 m^2)

Range of mother bulbs in grams	Number of umbels per plant	Grams of seed umbel	Grams of seed plant	Kg seed per 100^2
60- 80	2.2	3.6	7.8	16.6
80-100	2.4	3.4	8.4	18.2
100-150	2.8	3.4	9.5	20.2
150-200	3.3	3,2	10.4	21.7
Mean	2.7	3.4	9.0	19.2
Sign	***	*	***	***
LSD P=0.05	0.3	0.3	1.1	1.7

Plant density

It was obvious that number of umbels per plant, amount of seed per umbel and per plant were increased when there was a gradual decrease in number of plants per areal unit (Table 2). The total seed yield per 100 m^2, however, was highest with dense planting. The yield varied from 24.2 to 18.8 and 14.6 kg at a density of 3500, 1900 and 1200 plants per 100 m^2. The corresponding areal unit per plant was 200, 400 and 600 cm^2.

Table 2. The influence of plant density on number of umbels per plant, g seed per umbel and per plant and seed yield (kg per 100 m^2)

Number of plants per m^2	Distances between plants, cm	Cm^2 per plant	Number of umbels per plant	Grams seed per umbel	Grams seed per plant	Kg seed per 100 m^2
35	10 x 20	200	2.1	2.9	5.8	24.2
19	20 x 20	400	2.7	3.5	9.3	18.8
12	30 x 20	600	3.3	3.8	12.0	14.6
Mean			2.7	3.4	9.0	19.2
Sign.			***	***	***	***
LSD P=0.5			0.3	0.3	0.8	1.4

Seed yield values expressed in kroner

These calculations are based on the following costs: 450 mother bulbs set in the soil per hour at a cost of NOK 100, NOK 4 per kg mother bulb, and seed sold at a price of NOK 700 per kg. Owing to the different sizes of mother bulbs and plant densities the establishment expenses (transplanting at different distances) will vary somewhat. The total income of the seed yield minus the establishment expenses will give an indication of the income expected from the various plant densities and sizes of mother bulbs (Table 3).

Table 3. The influence of different sizes of mother bulbs and plant density on total income (kroner per m^2) minus the cost of mother bulbs and labour costs in a seed growing experiment with onions

Range of mother bulbs in grams	Number of plants per m^2 35	19	12	Mean
60- 80	125	101	82	103
80-100	148	115	87	113
100-150	149	130	92	123
150-200	145	133	109	129
Mean	142	117	92	

LSD: ($P=0.05$): Plant density and size of mother bulb = 11
LSD: ($P=0.05$): All data = 20

The result of the analysis of variance included the total income as well as the total income minus the establishment expenses. The higher the plant density, the smaller the sizes of mother bulbs which could be used in order to obtain the maximum income. The highest plant density (35 mother bulbs per 100 m^2) gave the best income, in average NOK 142 per m^2. The bulbs over 80 g gave the same income, NOK 147 per m^2, and a significantly bigger income than that from the smaller bulbs, (60-80 g) NOK 125 per m^2. At a smaller plant density (19 bulbs per m^2) the mean income was less, NOK 117 per m^2, and all the mother bulbs had to be over 100 g in order to obtain the greatest income, NOK 132 per m^2. At the smallest plant density (12 bulbs per m^2), the total income was smallest, with an average income of NOK 92 per m^2, and the mother bulbs had to be even bigger (150-200 g) in order to obtain the highest income, NOK 109 per m^2.

Growing sites

The seed yield for the seed crop raised in Grimstad in 1989 seemed to be the same as that grown in the district of Toten in 1988. The corresponding yields were 21.1 kg and 20.2 kg per 100 m^2. In 1988, however, the yield in Grimstad was 4.0 kg less per 100 m^2 than that in 1989. (Table 4). There was a special reason for this.

It was also observed that the range between these three experiments was the same in yield per umbel per plant as yield per 100 m^2. The number of umbels per plant, however, followed somewhat different pattern.

Seed quality

Weight of 1000 seeds and percentage of normal germinating seedlings are referred to as seed quality.

Size of the mother bulb and plant density had no influence on the seed quality, but the growing site had (Table 5). Germination percentages were over the standard requirement level on both growing sites, but were 9% higher in the seed crop from Grimstad

Table 4. The influence of growing site and season on number of umbels per plant, g seed per umbel and per plant and seed yield (kg per 100 m²)

Year	Growing district	Number of umbels per plant	Grams of seed per umbel	Grams of seed per plant	kg seed per 100 m^2
1988	Grimstad	2.8	2.9	8.2	16.2
1988	Toten	3.0	3.6	10.2	20.2
1989	Grimstad	2.3	3.8	8.7	21.1
Mean		2.7	3.4	9.0	19.2
Sign.		***	***	***	***
LSD P=0.05		0.3	0.3	0.8	1.4

than that from Toten, 94 and 85%. The germination speed, (germination percentage after 10 days) was also higher in the seed from Grimstad than in the seed from Toten, 82 and 54%. It was further observed that there were more ungerminated seeds in the seed crop from Toten than that from Grimstad. The differences between the weight of 1000 seeds grown in these regions seem to be very small.

Table 5. The influence of growing site and season on quality of onion seed

Year	Growing district	Grams per 1000 seeds	Percentage germination of seeds: Normal	Abnormal	Dead	Ungerm.	Speed of germ.
1988	Grimstad	3.7	95	0	2	3	80
1988	Toten	3.6	85	1	4	10	54
1989	Grimstad	3.5	93	1	2	4	83
Mean		3.6	91	1	3	6	72
Sign.		**	***	*	**	***	***
LSD P=0.05		0.1	3	1	1	3	3

DISCUSSION AND CONCLUSION

Size of mother bulb as well as plant density, independently influenced the size of the seed yield. However, these factors had no influence on the quality of the seed.

Plant density had the greatest effect on seed yield. A variation in the plant density from 12 (30 cm x 20 cm) to 35 bulbs (10 cm x 20 cm) per m^2 increased the yield by 66%, while an increase in the size of the mother bulbs from 60-80 g to 150-200 g, raised the yield by 31%. The biggest yield was obtained at the densest planting (10 cm - 20 cm), and at a mother bulb size of 100 g and over. The combination of factors producing the best results was more clear cut when the value of the yield was expressed in 'kroner'. Despite the higher cost of establishment, the greater plant density gave the best income, and mother bulbs of 80-100 g gave about the same income as the bigger ones.

Some foreign trials recommend mother bulbs of 80 g (Jones & Elmsweller 1939; Rusev 1978), others up to 200 g (Erskov 1974; Miccolis & Vitucci 1984). Rusev (1978) indicated that the ideal size of mother bulbs varied according to the varieties. In our case we used two varieties, but it is unlikely that they have had any influence on the main result, since both are very closely related (from the same population).

None of the trials abroad indicated that a too intense plant density decreased the yield. Neither was this the case in our experiment, with the exception of one (Jonassen, un-published), which had a much higher plant density than in any other experiment performed. This experiment showed no significant increase in the yield from 42 bulbs (10 cm x 20 cm) up to 62 (10 cm x 15 cm), and 84 bulbs (10 cm x 10 cm) per m^2. We chose (10 cm x 20 cm) as the smallest one for the densest planting. At dense planting the umbels were more likely to twist around each other, causing poor pollination and seed set, and also causing the harvesting work to be retarded.

The seed production capacity in the Toten area seems equivalent to that in the Grimstad area. The seed quality (germination percentage) was greater than the official requirement in both districts. However, the experiments showed that the germination percentage was higher (9%) and there were less ungerminated seeds in the seed crop cultivated at Grimstad than that at Toten. This is most likely attributable to the general climate in these districts. The transplanting of the mother bulbs can, however, be done earlier at Grimstad than at Toten, as can the harvesting earlier, because of a higher temperature in the harvest period at Grimstad than at Toten. The seed crop from Toten had more ungerminated seeds than that from Grimstad. The cause may, however, be that these seeds were still partly in dormancy when germination tests were carried out. The period between harvesting and germination tests was much shorter for the seed from Toten than for the seed from Grimstad.

SUMMARY

Experiments in seed growing in *Allium Cepa*, with the plant factors distance and size of mother bulb, were carried out in unheated greenhouses of plastic and glass at Toten and Grimstad in 1988 and 1989. Three different distances between the mother bulbs were included:

(1) 10 cm x 20 cm (2) 20 cm x 20 cm (3) 30 cm x 20 cm
There were four sizes of the mother bulbs, ranged in grams:
(1) 60-80 (2) 80-100 (3) 100-150 (4) 150-200

The seed yield increased by 66% from the greatest to the smallest plant distances (from the lowest to the highest plant density), and by 31% from the smallest to the biggest size of mother bulbs. The total income minus the cost of the mother bulbs, which varied according to their size and plant distance, indicated that the smallest plant distance (10 x 20), combined with size of the mother bulbs from 80 to 200 g (sizes 2, 3 and 4) gave an equivalent income and a clearly bigger one than that from mother bulbs smaller than 80 g. At the greater plant distances, ((2) and (3)) the income was lower, and the sizes of the mother bulbs had to be over 100 g and 150 g in order to obtain the maximum yield of these plant distances.

The factors distance between the mother bulb, and size of the mother bulb, had no influence on the quality of the seeds (weight of 1000 seeds and germination percentage). The yield capacity, however, seemed to be the same at the two growing sites.

b) Influence of different systems of seed production on seed yield and quality

Three different systems of onion seed production were compared at Landvik Research Station in 1988/1989. The purpose of the experiments was to recommend a system of onion seed production in Norway. The experiments included the following growing methods:

1. Seed-to-seed production.
2. Bulb-to-seed production. Transplanting in autumn.
3. Bulb-to-seed production. Transplanting in spring.

Earlier experiments involving methods 1 and 2 have been carried out by Vik (1984). These methods have several advantages, e.g. as to when the storing capacity of bulbs is low and as to saving expenses connected with storage. Other papers deal with the same problems (Rabinowitch & Brewster 1990).

Spring transplanting of mother bulbs in plastic houses is the most common method of seed production in Norway. However, comparisons between the three systems of seed production mentioned, particularly with regard to yield and quality of the seeds, have not been made earlier.

MATERIALS AND METHODS

In the-seed-to seed system, seeds were sown on 5 and 15 May. The autumn transplanted mother bulbs were transplanted on 10 October, and those transplanted in the spring on 7 April.

The size of the mother bulbs transplanted was 150-200 g. Mother bulbs overwintered in the field were provided with a 25 cm layer of spruce twigs, with an additional cover of plastic. This cover was removed 20 March. The bulbs for spring planting were kept in a ventilated store with temperatures varying from 1 to 8°C. A plastic house was placed over the whole experiment area on 7 April. From November until April, there were 148 days of temperatures over -5°C. The soil was covered with snow for only a few days. The mean temperature during the 1989 growing season and the normal temperature (mean of 30 years) were as follows:

Year	April	May	June	July	August	September
1989	5.3	11.0	14.1	16.6	14.5	11.8
Normal (30 years)	5.2	10.6	16.0	16.6	14.0	10.1

The experimental design comprised randomized blocks with three replicates. The plants were spaced in rows 10 cm apart, with 25 cm between rows (3 rows) and 50 cm between beds. This spacing gave a plant density of 2307 plants per 100 m^2. The seed crop was harvested once. Data recorded are listed in Tables 6 and 7. Germination tests were carried out according to international agreements.

RESULTS

Wintering, number of seed producing plants and growing period

The wintering of the plants was reasonably good.

At harvest the number of plants in the seed-to-seed system was reduced by 18% in relation to the original number (2307 per 100 m^2) and in the autumn transplanted motherbulbs by 29%. The number of spring transplants increased by 11% this as a result of the splitting of the mother bulbs (Table 6). The number of seed-producing plants in the seed-to-seed system was clearly less than that in the transplanted one. There was a clear significant difference between seed-to-seed system and transplanting system (autumn and spring), but not within each of these groups. The percentage of seed-producing plants was on average 54.4 and 99%.

Table 6. Influence of different methods of onion seed production on yield, number of plants, set of seed, total, and percentage of seed-producing plants

Date/year of drilling and transplanting	Yield of seed kg per 100 m^2	Yield of seed g per plant	Number of plants seed set	Number of plants total	percent seed prod. plants
5/5-88 drilling	4.3	4.3	1088	1889	58
15/5-88 drilling	4.0	3.7	1076	2137	51
10/10-88 transpl.	14.3	9.0	1615	1642	99
7/4-89 transpl.	18.7	7.3	2564	2047	99
Mean	10.3	6.1	1586	2047	76
Sign. level	***	***	**	**	***
LSD P=0.05	3.2	1.9	423	355	14

Since there were only small differences in seed ripening, the whole experiment was harvested once, on 23 August. Time of development from spring (7/4) to harvest was 138 days.

Seed yield

The spring transplanted mother bulbs gave significantly higher yield than the autumn transplanted bulbs, while both gave significantly higher yields than with the seed-to-seed method. There was no significant difference in seed yield between the two successive drillings. The yields, (kg per 100 m^2) were as follows: 18.7, 14.3, 4.2.

The yield per seed-producing plant was also clearly higher in the transplanted seed plants (autumn and spring) than in the drillings. The autumn transplanted mother bulbs had a higher yield per plant than the spring transplanted bulbs. The autumn and spring transplanted bulbs gave 9.0 and 7.3 g per seed plant, respectively, and the successive drillings 4.3 and 3.7 g.

Seed quality

The weight of 1000 seeds and the percentage of normal germination indicate the seed quality. None of the treatments influenced the quality (Table 7). Mean weight of 1000 seeds was 3.45 g and the germination percentage of normal seedlings after 10 and 14 days germinating time was 54 and 86. This table also indicates that the number of hard and ungerminated seeds was relatively high, close to 11%, and no difference was observed in any of the treatments.

Table 7. Influence of different methods of onion seed production on seed quality

Date/year of drilling and transplanting		g per 1000 seeds	Percent germination, hard and dead seeds				
			10 days	14 days			
			normal	normal	abnormal	hard	dead
5/5-88	drilling	3.47	44.3	86.3	1.0	10.3	2.7
15/5-88	drilling	3.44	53.0	85.3	0.7	11.7	2.3
10/10-88	transpl.	3.51	60.7	85.7	2.0	12.0	0.3
20/4-89	transpl.	3.39	57.0	87.3	1.3	9.7	1.7
Mean		3.45	53.8	86.2	1.3	10.9	1.8
Sign. level		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

DISCUSSION

This and earlier experiments (Vik 1984) show that with our climate the seed-to-seed method cannot be recommended. Wintering plants were too low, the differentiation of flower buds was too inferior, and consequently the yield small. However, transplanting the mother bulbs in the autumn seems promising and could be an alternative to transplanting in the spring. Autumn transplanting provides an opportunity to save on the cost of storage and transplanting in the spring. Autumn transplanting also seems to be advantageous to seed production of varieties or selections with inferior storing capacity. The spring transplanted plants gave a higher yield than those transplanted in the autumn, as a result of a greater number of seed-producing plants. The greater yield per seed-producing plant by autumn transplanting could not compensate for the lower number of seed- producing plants. Spring transplanting provided the opportunity to select for many more characters than with autumn transplanting, and increased the chances of obtaining the intended number of seed-producing plants.

The factors mentioned above, in addition to the climatic factors, have to be taken into consideration when deciding on a method for seed production in onion.

SUMMARY

During the season 1988/1989 experiments with different seed production methods in *Allium cepa* L. were carried out at Landvik Research Station. The seed-to-seed method was compared with that of transplanting full grown mother bulbs (150-200 g) in autumn and spring. In the seed-to-seed method, the sowing times were 5 and 15 May. Autumn transplanting took place on 10 October, and spring transplanting on 7 April. Transplanted mother bulbs in spring were stored throughout the winter at 1-8°C. The mother bulbs transplanted in the autumn were covered with a 25 cm layer of spruce twigs and an additional top layer of plastic. The seed fields were supplied with plastic houses from 7 April and throughout the whole growing season.

Both number of seed-producing plants and yield per plant influenced the seed yield. The differentiation and seed set in the autumn and spring transplanted mother-bulbs were very good, close to 100%, and gave the highest seed yield, 14.3 and 18.7 kg per 100 m^2, but per seed-producing plant the range was the opposite, 9.0 and 7.3 g. The lower seed yield in the autumn transplanted plants was due to a smaller number of seed-producing plants compared with spring transplanted bulbs. The yield in the seed-to-seed method was significantly lower: 4.3 and 3.7 kg per 100 m^2 in the successive drillings. This small yield was due to a small yield per seed producing-plant (mean 4 g), and a very low seed set (54%).

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Varietes du niebe en culture pluviale pour le Gourma au Mali

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Le niébé, est au Gourma, cultivé de façon peu répandue, et le plus souvent, en association avec le mil. Lors des essais en 1988, la pluviométrie a varié de 167 mm à 294 mm dans les quatre localités considérées dans cette étude. Le cycle des variétés testées a varié de 38 jours à 59 jours du semis à la floraison. Les variétés fleurissant 51-55 jours après le semis ont donné les meilleurs rendements. Les variétés qui conviennent le mieux à la culture au Gourma sont les variétés Rouge, Suivida 2, KVX 30-305-3G, et 58-57.

Mots clés: Mali, niébe, pluviométrie, précocité, variétés

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Le niébé (*Vigna unguiculata* (L.) Walp.) est en Afrique cultivé dans des milieux assez variés quant à la pluviométrie. Il existe des variétés qui fleurissent 30 jours après le semis et qui arrivent à maturité 55 jours après le semis, tandis que d'autres prennent plus de 90 jours à la floraison et achèvent leur cycle 210-240 jours après le semis (Wien & Summerfield 1984). Le niébé est très sensible aux maladies et aux attaques des insectes et, sans une protection chimique, les rendements sont souvent très faibles (IITA, 1988). En raison de ces faiblesses, un accent majeur quant à l'amélioration variétale du niébé est mis sur la résistance aux maladies et aux attaques des insectes. Au Sahel, une importance particulière est attachée au développement des variétés à double fin, à savoir grains et fane, et qui ont, en outre, une résistance à la sécheresse (IITA 1986, Singh & Ntare 1985).

Au Mali, il existe deux types de variétés du niébé (Kodio 1987): D'une part, les variétés sensibles aux jours courts, qui fleurissent quand l'ensoleillement devient inférieur à 12 heures/jour, quelle que soit la date du semis. Les variétés de ce type sont des variétés tardives et rampantes, qui sont cultivées dans les zones Centre et Sud du pays, où la pluviométrie est favorable. D'autre part, les variétés insensibles à la photopériode qui ont un port érigé ou semi-érigé et qui achèvent leur cycle 60-70 jours après le semis. Elles sont de ce fait, plutôt adaptées à la culture dans les zones Nord et Centre du pays. Le niébé est souvent cultivé comme une culture secondaire, associé au mil au nord du pays alors que, plus au sud, il est cultivé en association avec du sorgho ou du maïs (Kodio 1987). Le niébé est souvent semé 2-4 semaines après le mil lorsqu'il lui est associé (Renard et al. 1987). Au Gourma, le niébé est cultivé en culture pluviale au sud de l'isohyète de 300mm. Le niébé est ici, en particulier cultivé pour les grains, mais cela ne veut pas pour autant dire que le rendement en fane soit sans importance.

Le but de cette étude est de comparer les différentes variétés sélectionnées aux variétés locales, afin de déterminer quelles sont les variétés qui se prêtent le mieux à la culture pluviale.

MATERIELS ET METHODES

Quatre essais par année furent menés en 1987 et 1988 sur les localités Gossi, Timbajawen, Ebanguimellane et N'daki (figure 1). En 1987, seul un de ces quatre essais a donné un certain rendement du fait du manque de pluies. Les essais concernaient aussi une variété du pois mung (*Vigna radiata* (L.) Wilczek), pour réaliser, de même, une évaluation de cette espèce. Cela se justifie par le fait que son comportement diffère peu de celui du niébé.

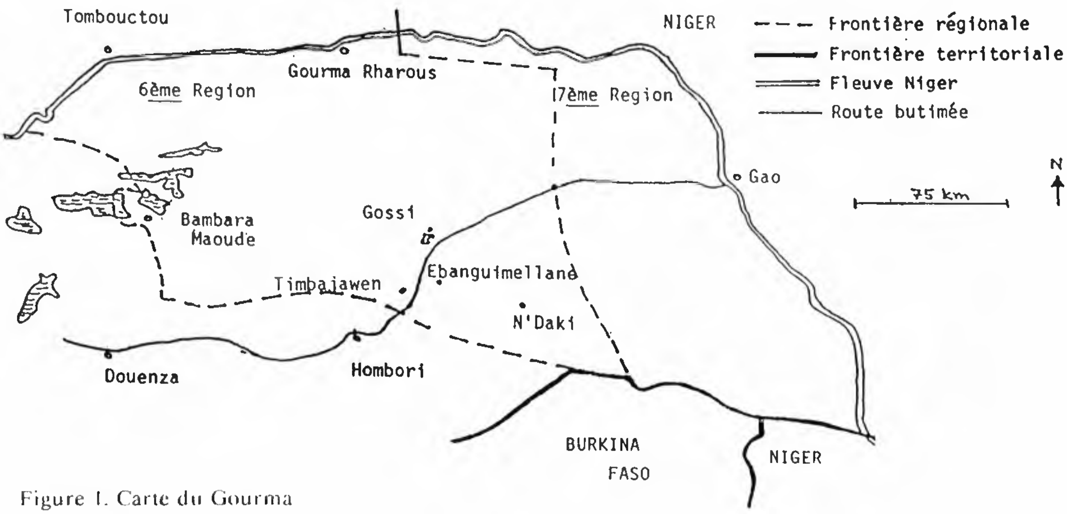

Figure 1. Carte du Gourma

Le dispositif expérimental a été celui du bloc de Fisher. En 1987, le semis fut réalisé à sec, sans aucun labour préalable du sol, alors qu'en 1988, le semis s'est fait sur des billons confectionnés à la houe. Les semis en 1988 furent effectués consécutivement à une pluie, sauf dans la localité de N'daki. Dans chaque poquet furent placés respectivement 4 grains et 8 grains de niébé et de pois mung. Deux à trois semaines après la levée, le démariage fut réalisé à raison d'une plante/poquet. Les différentes données expérimentales des essais sont consignées dans le tableau 1. Pendant la floraison un traitement avec l'insecticide Decis (Deltametrin) fut réalisé à Ebanguimellane, à N'daki et à Gossi. A Timbajawen, deux traitements furent effectués, mais lors du dernier traitement, seules deux des quatre répétitions furent traitées. Deux sarclages furent réalisés au cours de la campagne dans toutes les localités. Au cours de la campagne, de nombreux paramètres furent relevées. Le nombre de jours jusqu'à 50 % de floraison fut déterminé en comptant tous les 3 ou 4 jours, le nombre de plantes ayant des fleurs dans chaque parcelle. Le flétrissement et le recouvrement du sol par les plantes furent tous deux estimés à l'oeil nu. Le poids de 1000 grains fut déterminé en réalisant la pesée de 100 grains par parcelle. Le pourcentage en protéines fut déterminé par l'utilisation de la méthode de Kjeldahl. Les grains et la fane ont été séchés au moins pendant un mois avant d'être pesés.

Tableau 1. Données expérimentales des essais. Les mesures sont données en mètres

	1987	1988			
	N'Daki	Timbajawen	N'Daki	Gossi	Embanguimellane
Date du semis	1/07	14/07	21/07	13/07	14/07
Nombre de répétions	3	4	4	4	4
Parcelle (dimension)	2,8x7,0	2,8x7,0	2,8x7,0	1,8x6,6	2,8x7,0
Ècartement entre poquets	0,7x0,7	0,7x0,7	0,7x0,7	0,6x0,6	0,7x0,7
Première récolte	4/10	9/09	13/08	8/09	9/09

Les rendements en grains et en fane, et l'indice de rendement en 1988, sont corrigés par la levée avec une analyse de covariance. Ceci peut se justifier par le fait que l'effet de la levée sur les rendements des différents traitements n'a pas été trouvé significatif.

Lors des essais, toutes les variétés ne furent pas représentées sur tous les sites. Les analyses de variance pour l'ensemble des sites ont été effectuées en utilisant le programme de MSTAT qui estime les chiffres manquants. L'effet de la variété sur les différents paramètres fut testé contre l'interaction variétés(V)* localités(L). L'interaction V*L fut testée contre l'erreur déterminée par l'addition des sums de carres résiduele qui ressortent des différents essais. La ppds (plus petite différence significative) 5% est donnée là où elle est trouvée significative. Les niveaux de probabilité à 0,05, 0,01 et 0,001 sont respectivement indiqués par *, **, ***. L'abréviation n.s. signifie non significatif au niveau de probabilité de 0,05.

Des analyses de régression multiple furent effectuées en utilisant les rendements corrigés par la levée. La méthode de régression multiple fut celle de «step forward».

CONDITIONS PEDO-CLIMATOLOGIQUES

La faible pluviométrie et la répartition irrégulière des pluies en 1987 a contribué à l'échec des essais cette année-là. Au total, la pluviométrie à N'daki fut de 216mm en 1987. En 1988, les pluies furent surtout déficitaires à Gossi et à Ebanguimellane (tableau 2). La répartition des pluies fut meilleure à Timbajawen que sur les autres sites.

Le phosphore doit être considéré comme l'élément nutritif qui limite le plus les rendements au Sahel (Fussel et al. 1987). Bationo et al. (1989) ont estimé, dans les conditions sahéliennes, à 7,9 ppm selon la méthode de Bray 1 le niveau du phosphore disponible dans le sol qui permet d'obtenir 90% du rendement maximal. Cependant, l'analyse du sol utilisée pour le phosphore dans cette étude a été celle de Bray 2.

Tableau 2. Pluviométrie en 1988 (mm)

	Timbajawen	Ebanguimellane	N'Daki	Gossi
- > 20.6	0	0	12	16
21.6-30.6	0	3	4	6
1.7-10.7	17	19	16	13
11.7-20.7	9	8	20	17
21.7-31.7	31	22	42	19
1.8-10.8	53	81	85	28
11.8-20.8	87	15[1]	84	15
21.8-31.8	18	8	4	3
1.9-10.9	31	13	4	50
11.9-20.9	13	7	4	0
21.9-30.9	22	16	19	0
1.10-10.10	0	4	0	0
Totale	281	196	294	167

[1] measure incertaine

Lorsque ces deux méthodes furent comparées sur 30 différents sols au Nigeria, la quantité de phosphore extraite avec la méthode de Bray 1 et Bray 2 fut respectivement de 22,4 ppm et 27,1 ppm (Enwezor 1977), et la corrélation entre les deux méthodes fut élevée ($r^2 = 0{,}87$). Cela montre que ces deux méthodes sont proches l'une de l'autre. Il en suit que le besoin en phosphore semble être satisfait seulement à Gossi (tableau 3). Les analyses des différents sols montrent que le PH est assez favorable sur tous les sites. Les sols dans ces essais ont été très trouvés sablonneux avec un pourcentage de sable d'environ 90%.

Tableau 3. Résultats des analyses des sols dans la couche 0-20 cm (1) et dans la couche de 40-60 cm (2)

	Gossi		Ebanguim.		N'Daki		Timbajawen	
	1	2	1	2	1	2	1	2
PH (KCl)	6.2	6.5	5.8	6.1	5.2	5.0	5.8	5.7
P (Bray 2) ppm	21.0	18,3	3.4	1.7	3.2	18.8	2.2	39.8
CEC mé/100 g	2.0	1.7	0.5	1.3	0.6	1.3	1.5	2.5
Sable %	89.3	88.0	92.5	90.2	91.9	90.0	90.5	88.5
Limon %	2.3	1.7	1.7	1.8	1.5	1.1	2.2	2.0
Argile %	8.4	10.3	5.7	8.0	6.6	8.8	7.4	9.6

RESULTATS DES ESSAIS VARIETAUX

La faible pluviométrie de l'année 1987, n'a pas permis aux plantes de se développer de façon satisfaisante. En 1988, la pluviométrie, bien plus favorable, a permis une meilleure croissance des plantes, mais cette année-là aussi, les plantes ont connu une sécheresse au cours de leur cycle, en particulier à Gossi, mais aussi à Ebanguimellane. Les résultats concernent la levée, la précocité, le flétrissement, le recouvrement du sol, les rendements en grains et en fane, l'indice de rendement, le poids de 1000 grains et le pourcentage en protéines des grains.

Les variétés testées furent les variétés sélectionnées et les variétés locales Mopti et Rouge. La variété du pois mung testée fut la variété Celera.

Levée

A N'Daki, en 1987, la pluviométrie a été défavorable à un bon établissement de la culture, surtout dans le cas du pois mung (tableau 4). Les variétés Rouge, Suivida 2 et TN 88-63 ont eu la meilleure levée.

En 1988, la levée a été beaucoup plus satisfaisante sur l'ensemble des sites que l'année 1987, mais la levée à N'Daki a été un peu inférieure à celle des autres sites (tableau 4). L'interaction variétés(V) * localités(L) est due aux variétés KVX 30-305-3G, Rouge et B 99-2-1 qui ont eu une levée relativement faible à N'Daki, par rapport à celles des autres variétés et des autres sites.

Tableau 4. Levée (%) dans les différentes localités

	N'Daki	Timba-jawen	Ebangui-mellane	N'Daki	Gossi	Moyenne
	1987	1988				
Mopti	44,3	97,5	99,5	87,0	91,8	94,0
Rouge	64,3	97,0	100,0	77,5	93,3	92,0
Suivida 2	60,0	98,8	100,6	92,5	94,8	96,5
CB-5		88,8	99,5	87,0	94,8	92,5
IT 82D-699		90,8	98,8	90,0	95,5	93,8
B 99-2-1		95,0	100,0	80,0	96,4	92,9
IT 84 E108VR		95,0	97,5	88,3	93,3	93,5
KVX 396-4		97,5	99,3	82,5	97,0	94,1
KVX 30-305-3G		96,3	100,0	64,5	96,4	89,3
58-57		95,8	99,5	95,0	95,5	96,5
TN 88-63	57,5		100,0		90,9	92,1
Pois mung	2,5	99,5		100,0		100,0
TVX 32-36	35,8					
Giro 45581	32,5					
Giro 57317	22,5					
KVX 61-74	31,8					
Moyenne	39,0	95,5	99,5	85,8	94,5	93,8
ppds 5%	28,8	6,2	1,5	18,4	n.s.	n.s.
Interaction varietés*localites en 1988						*

Précocité

La floraison en 1987 a été très retardée en raison d'une sécheresse pendant le cycle. Les résultats obtenus alors, ne sont pas présentés ici. La variété Giro 45581 et le pois mung ont été les plus précoces en 1987.

En 1988, les pluies à Gossi ont été insuffisantes pour que toutes les variétés puissent arriver jusqu'à 50 % de floraison. De ce fait, la moyenne du nombre de jours jusqu'à 50

% de floraison est calculée en se fondant sur les résultats de Timbajawen et d'Ebanguimellane. Les variétés testées en 1988 semblent se distinguer en trois groupes en ce qui concerne la précocité (tableau 5). Parmi les variétés précoces, figurent CB-5 et IT 84 EI108VR ainsi que le pois mung. La première récolte pour CB-5 de même que pour le pois mung, a été effectuée 57 jours après le semis. Les variétés semi-précoces sont Rouge, Suivida 2, B 99-2-1, IT 82D-699, KVX 396-4, 58-57, TN 88-63 et KVX 30-305-3G. La variété KVX 30-305-3G est, parmi ces variétés, la plus tardive. Cettevariété ainsi que Mopti n'a pas pu atteindre 50% de floraison à Gossi. La variété Mopti s'est avérée être de loin la plus tardive. La période de formation des fleurs est apparue, de même, être plus étalée pour les variétés KVX 30-305-3G et Mopti que pour les autres. L'interaction V*L déterminée, est liée à la floraison relativement tardive de CB-5 et de IT 84 EI108VR et relativement précoce de KVX 396-4 à Ebanguimellane.

Tableau 5. Jours jusqu'à 50 % de floraison. La moyenne est calculée à partir des résultats de Timbajawen et d'Ebanguimellane

	Timbajawen	Ebanguimellane	Gossi	Moyenne
Mopti	59	58	-	59
Rouge	53	51	64	52
Suivida 2	55	52	64	54
CB-5	36	40	43	38
IT 82D-699	54	53	62	54
B 99-2-1	53	50	62	52
IT 84 EI108VR	39	43	48	41
KVX 396-4	55	50	54	53
KVX 30-305-3G	55	54	-	55
58-57	52	52	59	52
TN 88-63	51	56	51	
Pois mung	38	38		
Moyenne	50	50	57	50
ppds 5%	2,8	2,1	4,6	3,3
Interaction V*L				**

Flétrissement et recouvrement du sol au moment de la récolte

De grandes différences dans le flétrissement pendant la période de production des gousses ont été trouvées (tableau 6). La faculté qu'a une variété de garder ses feuilles vertes est importante, car elle lui assure une bonne qualité fourragère et lui confère une certaine souplesse en cas de période pluvieuse prolongée, la plante pouvant alors reprendre la croissance ultérieurement. Les variétés les plus tardives, à savoir Mopti et KVX 30-305-3G, sont les variétés du niébé qui ont gardé leurs feuilles vertes le plus longtemps. Cependant, dans le cas des autres variétés, la relation entre la précocité et le flétrissement n'est pas claire. Les variétés 58-57 et, surtout, KVX 396-4 n'ont pas conservé leurs feuilles vertes en fin de campagne.

En ce qui concerne le pourcentage de recouvrement du sol, les variétés précoces, comme CB-5, et IT 84 EI108VR et le pois mung se sont révélées moins efficaces que les autres (tableau 6). Ceci reflète le port érigé des variétés précoces alors que les variétés plus tardives sont plus ou moins rampantes.

Tableau 6. Flétrissement (%) (moyenne de Timbajawen, Ebanguimellane et N'daki) et recouvrement du sol des plantes (%) à Timbajawen

	Flétrissement %	Recouvrement %
Mopti	6,7	96,3
Rouge	38,4	78,8
Suivida 2	35,7	73,8
CB-5	42,7	28,8
IT 82D-699	39,3	48,8
B 99-2-1	36,7	82,5
IT 84 EI108VR	28,0	32,5
KVX 396-4	59,7	72,5
KVX 30-305-3G	24,0	72,5
58-57	48,7	73,8
TN 88-63	40,0	
Pois mung	22,0	31,3
Moyenne	35,2	62,9
ppds 5%	13,8	12,6
Interaction V*L	n.s.	

Rendement en grains

Les rendements en grains obtenus en 1987 à N'Daki ont été faibles par rapport aux rendements obtenus en 1988 (tableau 7). En 1988, le rendement le plus élevé a été enregistré à Timbajawen, alors que le rendement le plus faible a été obtenu à Gossi.

En 1987 à N'daki, les variétés Rouge et Suivida 2 ont donné les rendements les plus élevés (tableau 7).

Pour l'ensemble des sites en 1988, les variétés Rouge, KVX 30-305-3G, TN 88-63, KVX 396-4, Suivida 2 et 58-57 ont donné les meilleurs rendements, et ces variétés n'ont pas beaucoup différé l'une de l'autre (tableau 7). Le pois mung, et les variétés Mopti et IT 84 EI108VR se sont révélées le moins performantes.

La performance des variétés s'est avérée fortement variable suivant la localité. La variété la plus tardive, Mopti, a donné un rendement élevé à Timbajawen alors que son rendement a été très faible à Gossi et à Ebanguimellane. Les variétés B 99-2-1 et IT 84 EI108VR ont aussi donné des rendements relativement faibles à Gossi. La variété précoce CB-5 a présenté un rendement relativement faible à Timbajawen par rapport aux autres variétés.

Rendement en fane

Toute comme pour le rendement en grains, le rendement en fane a été très faible en 1987 (tableau 8). Cette année là, les variétés Rouge et Suivida 2 ont donné les meilleurs rendements.

Pour l'ensemble des sites en 1988, Mopti a donné un rendement en fane bien supérieur à celui des autres variétés (tableau 8). Les variétés précoces et érigées, à savoir le pois mung, CB-5 et IT 84 EI108VR, ainsi que IT 82D-699, ont donné un rendement faible en fane. L'interaction V*L est liée aux variétés IT 82 D-699 et CB 5 qui ont donné un rendement relativement faible à Timbajawen par rapport à celui des autres variétés. De même, le rendement à Ebanguimellane relativement élevé de KVX 396-4 et relativement faible de 58-57 a contribué à l'interaction V*L. A Gossi, le rendement de KVX 396-4 s'est avéré relativement faible.

Tableau 7. Rendement en grains (kg/ha)

	N'Daki	Timba-jawen	Ebangui-mellane	N'Daki	Gossi	Moyenne
	1987	1988				1988
Mopti	15	669	65	179	27	235
Rouge	75	762	415	494	184	464
Suivida 2	57	649	456	472	175	438
CB-5		463	399	392	107	340
IT 82 D-699		429	302	283	112	281
B 99-2-1		597	299	379	46	330
IT 84 E1108VR		390	321	257	62	257
KVX 396-4		781	457	456	118	453
KVX 30-305-3G		784	392	502	170	463
58-57		707	355	461	168	422
TN 88-63	13		444		205	456
Pois mung	0	406		42		94
TVX 32-36	14					
Giro 45581	14					
Giro 57317	4					
KVX 61-74	17					
Moyenne	26	603	355	356	125	353
ppds 5%	30	254	86	86	53	112
Interaction V*L						***

Tableau 8. Rendement en fane (kg/ha)

	N'Daki	Timba-jawen	Ebangui-mellane	N'Daki	Gossi	Moyenne
	1987	1988				1988
Mopti	112	1340	803	710	690	886
Rouge	174	850	398	340	355	486
Suivida 2	180	815	410	413	361	500
CB-5		380	241	319	261	300
IT 82D-699		335	362	283	216	299
B 99-2-1		742	536	476	410	541
IT 84 E1108VR		358	265	246	177	262
KVX 396-4		623	534	300	226	421
KVX 30-305-3G		757	411	338	328	459
58-57		928	421	405	418	543
TN 88-63	69		472		410	512
Pois mung	1	255		66		95
TVX 32-36	64					
Giro 45581	43					
Giro 57317	75					
KVX 61-74	83					
Moyenne	89	671	441	354	350	442
ppds 5%	83	199	104	109	108	148
Interaction V*L 1988						***

L'indice de rendement
L'indice de rendement à Gossi, en 1988, a été plus faible que sur les autres sites. En 1988, ce sont les variétés précoces qui ont montré les indices de rendement les plus élevés, alors que la variété Mopti, qui est tardive, a donné un indice de rendement beaucoup plus faible (tableau 9). L'interaction V*L peut être due au fait que l'indice de rendement de la variété Mopti s'est montré beaucoup plus faible à Gossi et à Ebangui-mellane que dans les autres sites. De même, le faible indice de rendement de B 99-2-1 à Gossi a contribué à cette interaction.

Poids de 1000 grains
Ce furent surtout le pois mung, mais aussi les variétés 58-57, TN 88-63 et IT 82D-699 qui ont donné de petits grains (tableau 10). La variété KVX 30-305-3G est celle ayant, de loin, les plus gros grains. Le poids de 1000 grains des différentes variétés s'est avéré dépendant du milieu.

Tableau 9. Indice de rendement

	N'Daki	Timba-jawen	Ebangui-mellane	N'Daki	Gossi	Moyenne
	1987	1988				1988
Mopti	11,8	33,0	7,7	20,4	3,1	16,2
Rouge	30,1	47,0	50,8	54,5	33,0	47,5
Suivida 2	24,1	43,7	51,8	53,2	32,0	45,2
CB-5	52,1	63,3	54,4	28,0	49,2	
IT 82D-699		53,4	47,0	50,1	31,7	45,6
B 99-2-1		43,7	35,9	46,3	10,0	34,0
IT 84E1108VR		51,9	57,6	52,9	25,1	46,9
KVX 396-4		55,3	47,7	60,5	34,8	49,6
KVX 30-305-3G		50,5	48,2	61,9	34,6	48,8
58-57		43,3	46,3	52,9	28,7	42,8
TN 88-63	24,1		48,3		33,3	50,1
Pois mung	0,0	63,3			50,1	47,0
TVX 32-36	17,9					
Giro 45581	24,6					
Giro 57317	5,0					
KVX 61-74	17,0					
Moyenne	22,6	51,2	50,0	51,2	26,7	43,5
ppds 5%	5,9	9,5	13,0	84,2	9,6	8,6
Interaction V*L						***

Protéines
Les variétés IT 82D-699, IT 84 E1108VR et 58-57 sont celles qui ont présenté le pourcentage en protéines le plus élevé (tableau 11). Les variétés TN 88-63, B 99-2-1 et CB-5 ont donné la teneur en protéines la plus faible. On peut remarquer que la teneur en protéines du pois mung s'est révélée être aussi importante que celle des différentes variétés du niébé. Toute comme pour le poids de 1000 grains, le pourcentage en protéines des différentes variétés s'est avéré dépendant du milieu.

Tableau 10. Poids de 1000 grains (g)

	Timbajawen	Embanguimellane	N'Daki	Moyenne
Mopti	179	176	167	174
Rouge	199	198	180	193
Suivida 2	198	200	184	194
CB-5	195	199	208	201
IT 82D-699	111	140	126	126
B 99-2-1	145	157	145	149
IT 84 E1108VR	150	168	158	159
KVX 396-4	170	168	156	164
KVX 30-305-3G	226	275	217	253
58-57	126	111	111	116
TN 83-63		120		116
Pois mung	35		38	39
Moyenne	161	174	153	163
ppds 5%	18	14	17	17
Interaction V*L				***

Tableau 11. Pourcentage en protéins des différentes variétes

	Timbajawen	Embanguimellane	N'Daki	Moyenne
Mopti	24,6	25,0	23,8	24,5
Rouge	25,1	24,6	22,3	24,0
Suivida 2	25,3	24,5	22,5	24,1
CB-5	24,9	22,4	22,2	23,2
IT 82 D-699	25,9	26,8	25,1	25,9
B 99-2-1	22,4	23,0	21,4	22,3
IT 84 E1108VR	26,6	26,2	23,7	25,5
KVX 396-4	24,9	24,7	23,4	24,3
KVX 30-305-3G	24,0	25,2	22,4	23,9
58-57	25,5	25,5	23,5	24,8
TN 88-63		22,5		22,1
Pois mung	25,3		23,3	24,6
Moyenne	25,0	24,6	23,1	24,1
ppds 5%	1,8	0,7	0,7	0,9
Interaction V*L				**

Relation entre les rendements en grains et en fane et la précocité, le flétrissement et le recouvrement du sol

Pour pouvoir examiner les relations entre les rendements et les différents facteurs qui peuvent l'influencer, de analyses de régression multiple furent effectuées.

Timbajawen, une relation entre les rendements (grains et fane) et la précocité, le flétrissement et le recouvrement du sol par le feuillage a été examinée, et il s'est avéré que seul le recouvrement a contribué de façon significative à expliquer le rendement en grains ($r^2 = 0,67$) (figure 2). Le rendement en fane n'a pas contribué à expliquer le rendement en grains, lorsque le recouvrement du sol a été rentré en première position dans l'analyse de régression multiple. Une relation entre les facteurs ci-dessus et le rendement en fane a aussi été recherchée à Timbajawen, et il s'est avéré qu'une fonction du 2nd degré entre le pourcentage de recouvrement du sol et le rendement en fane ($r^2=0.91$) a expliqué le plus le rendement en fane (figure 2).

A Ebanguimellane, la relation entre les rendements d'un côté et la précocité et le flétrissement de l'autre côté a été analysée. Ici, une fonction significative du 2nd degré a été trouvée entre le nombre de jours jusqu'à 50 % de floraison et le rendement en grains ($r^2=0,61$) (figure 3). Le rendement en fane n'explique pas de façon significative le rendement en grains, lorsque la précocité a été rentrée en première position dans l'analyse de régression multiple. Il existe une relation linéaire significative entre le rendement en fane et la précocité ($r^2=0,56$) (figure 3).

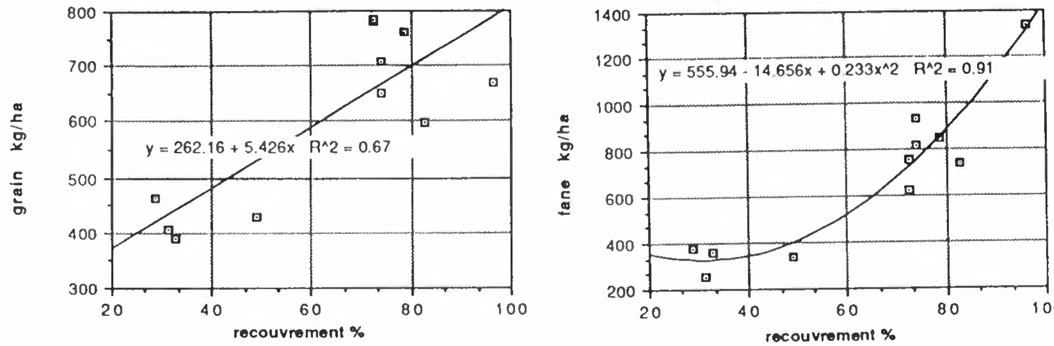

Figure 2. Relation entre le recouvrement du sol des plantes et les rendements à Timbajawen

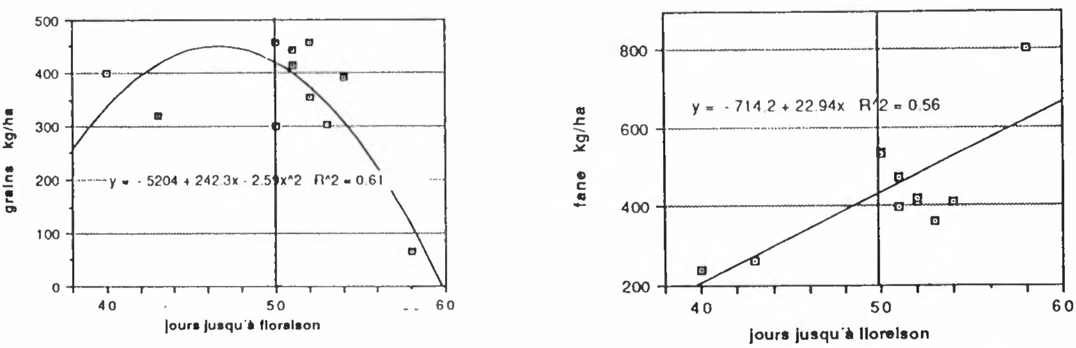

Figure 3. Relation entre le nombre de jours jusqu'à la floraison et les rendements à Ebanguimellane

Pour l'ensemble des 4 localités, une fonction significative du 2nd degré a été trouvée entre le nombre de jours jusqu'à 50 % de floraison et le rendement en grains ($r^2=0,55$) (figure 4). La moyenne des localités Timbajawen et Ebanguimellane fut ici utilisée pour la précocité. Le flétrissement n'a donné une contribution significative pour expliquer le rendement en grains lorsque la précocité a été rentrée en première position dans l'analyse. Entre le nombre de jours jusqu'à la floraison et le rendement en fane, une relation linéaire significative ($r^2=0,63$) a été trouvée pour les 4 localités (figure 4).

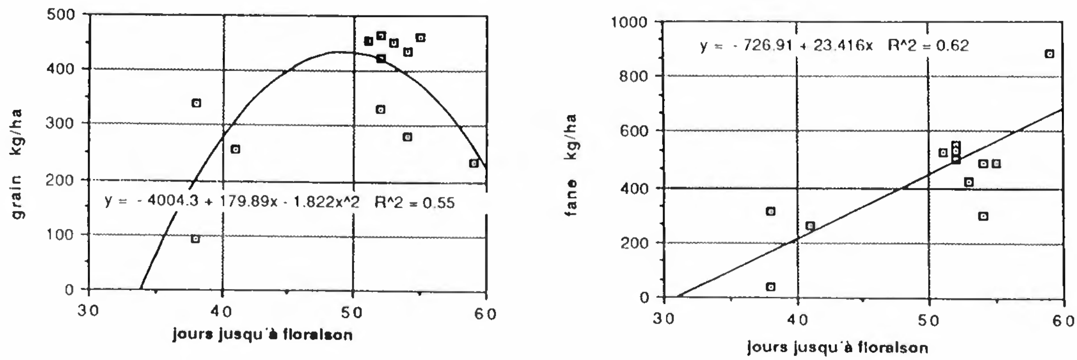

Figure 4. Relation entre le nombre de jours jusqu'à la floraison et les rendements en utilisant les chiffres moyens

DISCUSSION

L'accent de la discussion portera surtout sur les résultats obtenus en 1988, car les rendements cette année-là ont été les plus intéressants.

Le renseignement le plus important obtenu de l'année 1987, est celui que les variétés Suivida 2 et Rouge se sont montrées assez adaptées à la zone. Ce résultat est confirmé par les résultats de 1988.

En 1988, la levée a été satisfaisante sur l'ensemble des sites. Ce sont surtout les résultats de N'daki qui ont engendré l'interaction V*L (tableau 4). L'erreur statistique est beaucoup plus élevée à N'daki que pour les autres sites comme le reflète la ppds 5%. Il existe donc certaines incertitudes en ce qui concerne les chiffres obtenus sur ce site, et il se pourrait que l'interaction V*L puisse être attribuée à ces aléas.

Dans les essais menés au Gourma le nombre de jours jusqu'à 50 % de floraison a bien reflété à vu d'oeil, le classement entre les différentes variétés quant au cycle complet de chaque variété, sauf en ce qui concerne le pois mung, qui semble avoir un cycle reproductif plus court que celui des variétés du niébé.

Des différences nettes quant au nombre de jours jusqu'à 50 % de floraison sont apparues, et une interaction V*L a été trouvée (tableau 5). Cette interaction pourrait être partiellement attribuée à une sécheresse intervenue pendant le cycle végétatif des plantes à Ebanguimellane provoquant un retard plus important pour les variétés à floraison précoces que pour les autres variétés, car ces dernières ont bénéficié d'un temps plus important pour rattraper le retard.

Dans le choix d'une variété au Gourma, le cycle de cette variété est important, car il faut que la variété puisse compléter son cycle avant l'arrêt des pluies. Les analyses de régression fournissent quelques renseignements importants à cet égard. A Timbajawen, où la pluviométrie a été relativement favorable, la précocité n'a pas contribué à expliquer le rendement en grains, lorsque le recouvrement du sol a été rentré en première position dans l'analyse (figure 2). Ceci indique que la précocité n'est pas un facteur important pour le rendement en grains lorsque la pluviométrie est relativement favorable et bien répartie. A Ebanguimellane, où la pluviométrie a été beaucoup plus faible (tableau 3), la fonction de 2nd degré trouvée entre le nombre des jours jusqu'à la floraison et le rendement en grains, indique que les variétés tardives ont, ici, un handicap par rapport aux autres variétés (figure 3). Cependant, il convient de souligner que cette fonction est surtout déterminée par la variété Mopti. Pour l'ensemble des 4 localités, la fonction de 2nd degré trouvée entre le nombre de jours jusqu'à la floraison et le rendement en grains, indique que les variétés ayant un cycle au moins aussi longue que celui de Mopti ne sont pas adaptées à la zone étudiée (figure 4). Il est cependant important de signaler que l'effet de la précocité est confondu avec celui du port des variétés, donc ces résultats doivent être utilisés avec réserve (voir ci-dessous).

En ce qui concerne les rendements en grains, de différences nettes entre les variétés sont apparues (tableau 7). Cependant, il est à souligner que l'écartement entre poquets n'a pas permis aux variétés précoces et érigées, à savoir «pois mung», CB-5 et IT 84 E108VR, d'atteindre leur potentiel maximal, car elles n'ont pas recouvert le sol aussi bien que les variétés rampantes. Il aurait fallu les semer de façon plus dense, pour qu'elles atteignent leur potentiel maximal. Il existe donc certaines incertitudes quant à la comparaison entre variétés précoces et tardives.

La performance en rendement en grains des différentes variétés s'est avérée dépendant du milieu. La variété CB-5 n'a pas profité autant que les variétés tardives des bonnes conditions climatiques de Timbajawen, alors que la variété tardive Mopti a ici, donné un rendement relativement élevé. Cette dernière variété a donné un rendement en grains très faible à Gossi et à Ebanguimellane, qui sont les sites qui ont eu la pluviométrie la plus faible. Les variétés B 99-2-1 et IT 84 E108VR se sont, aussi, avérées peu productives à Gossi. L'interaction V*L peut de même être attribuée à une attaque de foureuse des gousses (*Maruca testulalis*) constatée en particulier sur les variétés précoces à Timbajawen. Il est aussi possible qu'une attaque des trips (*Melanurothrips sjostedti*) pendant la plus forte période de pluie, ait diminué davantage les rendements pour les variétés précoces que pour les variétés tardives, ceci du fait que la floraison des variétés précoces a coïncidé avec cette période de pluie.

Les variétés Suivida 2, KVX 30-305-3G, 58-57 et TN 88-63 ont, par ailleurs, été testées dans d'autres localités mieux arrosés que celles du Gourma (Hullet 1985, Kodio & Traoré 1988, SRCVO 1989, ICRISAT Centre Sahélien 1986, IITA 1986). Il ressort de ces essaisque toutes ces variétés sont bien adaptées aux conditions sahéliennes. En particulier, la variété KVX 30-305-3G s'est avérée performante (IITA 1986).

En ce qui concerne le rendement en fane, de grandes différences ont été trouvées entre les variétés étudiées (tableau 8). Il convient de souligner que les différents rendements en fane sont légèrement sous-estimés, en raison du vent qui a emporté une partie de feuilles sèches avant qu'elles n'aient pu être récoltées. L'interaction V*L apparue, ici, est difficile à expliquer, mais l'un des facteurs qui a pu engendré l'interaction pourrait être le fait que les variétés les plus tardives ont profité davantage des bonnes conditions climatiques de Timbajawen, car le CB-5 a donné un rendement relativement faible à Timbajawen.

Les faibles indices de rendement à Gossi s'expliquent par la faible pluviométrie qui y a été observée (tableau 9). L'interaction V*L, ici, est en partie due à la variété Mopti qui n'a pas pu achever son cycle à Ebanguimellane et à Gossi. L'indice de rendement montre ainsi, l'adaptation des variétés à la zone étudiée.

Le poids de 1000 grains (tableau 10) est un paramètre important à considérer, car les variétés à gros grains sont habituellement les plus facile à décortiquer (SRCVO 1989). De ce point de vue, KVX 30-305-3G présente un intérêt particulier, ayant de très gros grains. L'interaction V*L, ici, est difficile à expliquer, car elle est déterminée par de nombreux facteurs comme le développement végétatif, la résistance à la sécheresse, le nombre de fleurs formées et la perte des fleurs.

Après la sécheresse qu'a connue le Gourma durant les années 80, le nombre d'animaux présents dans cette zone a diminué, rendant nécessaire le développement de sources proteiques supplémentaires pour assurer à la population un apport minimal en protéines. Le niébé, grâce à sa teneur en protéines élevée, peut ainsi, jouer un rôle important dans l'alimentation de la population locale. Des différences en ce qui concerne la teneur en protéines entre les diverses variétés ont été trouvées (tableau 11), mais elles sont restées relativement minimes. L'interaction V*L, ici, est aussi difficile à expliquer que celle trouvée dans le cas du poids de 1000 grains, car les facteurs qui influencent le poids de 1000 grains jouent de même sur le pourcentage en protéines. En plus des facteurs cités précédemment, la fixation d'azote a probablement eu une influence majeure, ici.

Dans le choix d'une variété, le rendement en grains et en fane et la stabilité de ces rendements sont les facteurs déterminants. Les autres facteurs influençant le choix sont le flétrissement, la précocité, la taille des grains et l'acceptabilité culinaire. Les variétés Rouge, Suivida 2, KVX 396-4, KVX 30-305-3G, TN 88-63 et 58-57 se sont révélées être les plus performantes en ce qui concerne le rendement en grains. Cependant, la variété KVX 396-4 a montré un flétrissement plus accentué que les autres variétés précitées, ce qui lui confère un défaut par rapport à celles-ci. La variété TN 88-63 semble avoir un goût moins apprécié que les autres variétés, ce qui la rend moins intéressante que celles-ci (Ntare, communication personnelle). En ce qui concerne le rendement en fane, la variété Mopti a donné les meilleurs résultats, suivi par les variétés mentionnées ci-dessus. Cependant, Mopti ne peut pas être préconisée, du fait de son trop faible rendement en grains, et de son caractère tardif. Les variétés Suivida 2, Rouge, 58-57 et KVX 30-305-3G semblent donc être les plus intéressantes ici. Suivida 2 et Rouge sont analogues du point de vue de la couleur des grains, du comportement végétatif, de la précocité, de la teneur en protéines et du poids de 1000 grains. Il est donc possible qu'elles ne constituent qu'une seule variété.

Le niébé sera au Gourma vraisemblablement semé en association avec le mil, selon la tradition. Il faut donc prendre en considération la concurrence interspécifique entre ces deux espèces. Il a été trouvé que les variétés les plus tardives et les plus vigoureuses sont celles qui ont diminué le plus les rendements du mil (Ntare 1989). Les variétés précoces et érigées présentent ici un avantage, mais les défauts attachés à ces variétés sont la vulnérabilité aux maladies et aux attaques des insectes (IITA 1985), un faible rendement en fane et une moindre souplesse lors d'un prolongement de la période pluvieuse. Il a été montré, de même, lors d'un essai réalisé au nord du Burkina Faso, que les variétés très précoces sont vulnérables aux tempêtes de sable. Il en résulte qu'elles ne peuvent pas être considérées comme vraiment adaptées aux conditions sahéliennes (IITA 1984). De ce fait, elles sont probablement moins adaptées aux conditions climatiques du Gourma que les variétés qui fleurissent 51-55 jours après le semis et qui achèvent leur cycle en 70-75 jours.

En se fondant sur cette étude, il est possible de conclure que les variétés qui conviennent le mieux à la culture pluviale à Gourma sont Suivida 2, Rouge, KVX 30-305-3G et 58-57.

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Tecniques culturales pour le mil au Gourma malien

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Le mil est traditionnellement dans le Gourma au Mali semé sans labour préalable du sol, et le sarclage consiste d'un simple grattage superficiel du sol. Un essai mené en 1987 a montré qu'il est préférable de semer sur les flancs des billons parce que les plantes y sont plus à l'abri des tempêtes de sable. Le rendement en 1987 sur les billons a dépassé, de loin, les rendements sur les parcelles non-labourées. En 1988, aucune différence significative en ce qui concerne le rendement en grains n'est apparue entre les différentes méthodes testées.

Mots clés: Erosion eolien, labour du sol, pennisetum glaucum, variétés.

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Au Mali, le sud du Gourma, qui est la zone dans laquelle cette étude fut menée, se caractérise climatiquement par une faible pluviométrie annuelle, d'environ 300mm, et par l'irrégularité des pluies. La culture du mil est, ici, une culture très extensive. Presque aucun labour proprement dit, ni aucun apport d'engrais ne sont réalisés. Ceci s'explique du fait que la pluviométrie favorise le nomadisme qui est le mode de vie principal de la population au Gourma, et les paysans n'attachent qu'un intérêt secondaire à l'agriculture. De plus, l'infrastructure presque inexistante, rend la distribution et la vente du matériel de production très difficiles. Enfin, la recherche n'accorde qu'un intérêt mineur à cette zone, et, ainsi, aucune technique permettant d'augmenter les rendements n'a été mise au point.

Dans la culture traditionnelle au Gourma, le mil est semé en poquets distants d'environ 1 m. Le semis est réalisé sans labour préalable du sol, avant le commencement des pluies normalement à partir du début juin. Entre 20 et 40 grains sont placés dans chaque poquet. Cependant, plusieurs semis sont souvent nécessaires à cause de l'arrêt fréquent des pluies. Le démariage est fait 2-3 semaines après la levée, à raison de 2-5 plantes/poquets. Le sarclage est réalisé suivant deux méthodes, décrites dans le chapitre «matériels et méthodes».

Le but de cette étude a été d'essayer de mettre au point une méthode de labour du sol qui puisse à la fois augmenter et assurer les rendements. Les nouvelles méthodes testées, ici, se sont inspirées de la recherche effectuée plus au sud, au Sahel.

MATERIELS ET METHODES

L'essai mené à Gossi en 1987 a été un essai factoriel, alors que le dispositif utilisé en 1988 a été celui du Bloc de Fischer. Les données expérimentales sont consignées dans le tableau 1. En 1988, l'on a essayé de diminuer l'effet possible entre parcelles voisines sur le rendement en semant 6 lignes (parcelle élémentaire), dont seules les 4 lignes du milieu ont été récoltées (parcelle outil). La variété locale Hombori fut la variété utilisée.

Tableau 1. Données expérimentales. Les dimensions sont données en mètre

	Gossi 1987	N'Daki 1988	Timbajawen 1988	Ebanguimellane 1988
Date du semis	15/8[1]	24/8	20/6	10/6
Parcelle élémentaire	5,4*3,6	6,3*5,4	7,2*5,4	6,3*5,4
Parcelle outil	-	6,3*3,6	7,2*3,6	6,3*3,6
Ècartement entre poquets	0,9*0,9	0,9*0,9	0,9*0,9	0,9*0,9
Nbr. de répétitions	3	4	4	4

[1] dernier semis

Les traitements en combinaison factorielle testés en 1987 ont été comme suit:
Labor du sol:
1. Aucun labour du sol
2. Billon. Les billons était distantes de 90 cm et avaient une hauture d'environ 20 cm

Paillage:
1. Aucun apport de paille
2. Apport de paille sur la surface à du sol équivalant à 3 t/ha

Dans cet essai, aucun sarclage au cours de la saison ne fut réalisé, car il n'y avait pas d'adventifs.

Les méthodes testées en 1988 furent comme suit (les deux premières méthodes sont les méthodes traditionnelles):

1. Sarclage avec le hiliare (outil qui se compose d'un manche et d'un lame au bout du manche). Cette méthode consiste à pousser l'hiliare de manière à ce que les adventifs soient coupés au niveau de la surface du sol au moment du démariage. Ce sarclage est répété une fois pendant la culture.
2. Méthode de buttes. Le sarclage est effectué de manière à confectionner à la houe des buttes entre les poquets de mil. Ces buttes, d'une hauteur d'environ 25cm, se composent des adventifs déracinés et de la surface du sol. Le deuxième sarclage est fait de façon à augmenter davantage les dimensions des buttes. L'année suivante le cultivateur sèmera sur ces buttes, et l'enracinement pourra éventuellement s'en trouver amélioré.

3. Labour à plat. Le sol est labouré à la houe jusqu'à une profondeur d'environ 10cm. Les sarclages sont aussi réalisés à la houe.
4. Billon. Les billons, confectionnés à la houe, sont distants l'un de l'autre de 90cm et ont une hauteur de 20-25cm. Le sarclage a, ici, été effectué de façon à reconstituer les billons, car le vent avait tendance à araser la crête des billons.
5. Zai. Une méthode en provenance du Burkina Faso. Elle consiste à faire des trous d'une profondeur d'environ 15cm et de dimension d'environ 20cm * 20cm dans lesquels les semences sont placés. Le sarclage est fait avec le hiliare.

Le labour du sol en 1987 fut éffectué suite dune pluie alors que en 1988 le sol était sec quand le labour a eu lieu.

Pour tous les traitements, deux sarclages furent effectués au cours de la saison. Les observations au cours de la saison furent relevées pour chaque parcelle afin de pouvoir réaliser des analyses statistiques. Les observations furent prises de la manière suivante.

- la levée: en comptant tous les poquets dans lesquels il y avait des plantes.
- la hauteur des plantes à Gossi, en 1987, fut relevée 24 jours après le semis avant l'épiaison, alors que les mesures de la hauteur des plantes en 1988 expriment la longueur de la tige jusqu'au commencement de l'épi.
- poids de 1000 grains: 200 grains furent pesés.
- les récoltes en grains et en paille furent sechés au moins pendant 1 mois avant d'être pesées.

Les analyses de variance furent effectuées avec le programme de MSTAT. L'effet de la méthode pour les différents paramètres fut testé contre l'interaction méthode(M)* localités(L). L'interaction M*L fut testée contre l'erreur résiduelle. La ppds (plus petite différence significative) 5% est donnée là où elle est trouvée significative. Les niveaux de probabilité à 0,05, 0,01 et 0,001 sont respectivement indiqués par *, **, ***. L'abréviation n.s. signifie non significatif au niveau de probabilité de 0,05.

Pour évaluer l'effet des différentes méthodes de labour du sol sur les conditions hydriques, des échantillons de sol furent prélevés sur un bloc adjacent, pour éviter d'influencer sur les essais du rendement. Les échantillons furent pris avec des cylindres ayant un volume de $100cm^3$, dans différentes couches du sol. Dans chaque couche, 4 cylindres furent prélevés et le sol fut pesé à l'état humide et à l'état sec. A N'daki, les échantillons furent prélevés dans les couches 8-12cm et 35-39cm. A Timbajawen, les prélèvements furent effectués deux fois au cours de la saison, la première fois dans la couche 8-12cm et 23-27cm et la deuxième fois comme à N'daki. A Ebanguimellane, les prélèvements ont uniquement été effectués dans la couche 30-34cm, car la couche supérieure était sèche lorsque l'échantillonnage fut réalisé. Avant d'effectuer les analyses statistiques, la moyenne à Timbajawen des deux fois où les prélèvements ont été réalisés a d'abord été calculée. Ensuite, la moyenne des résultats des deux profondeurs fut calculée pour les localités de N'daki et de Timbajawen. Des analyses de variance furent réalisées, les 3 localités étant les répétitions.

Les échantillons de sol destinés aux analyses chimiques se sont composés de 10 sub-échantillons, pris d'une manière aléatoire sur chaque site examiné. Un pluviomètre fut installé sur chaque site d'expérimentation.

CONDITIONS PEDOCLIMATOLOGIQUES

La pluviométrie à Gossi en 1987 a été très déficitaire et elle n'a été que 145mm. L'année 1988 a connu une pluviométrie bien plus favorable que l'année précédente (tableau 2). Les pluies ont commencé tardivement en 1988, à partir du 9 juillet. Ces pluies ont permis un bon établissement des plantes lors des essais. A Ebanguimellane, les conditions hydriques ont été favorables à partir du 9 juillet, mais les précipitations ont été faibles au mois de septembre. N'daki et Timbajawen ont enregistré la meilleure pluviométrie, mais la répartition des pluies a été irrégulière à partir du 20 août à N'daki. A Timbajawen, les pluies ont été mieux réparties, mais les plantes ont montré, malgré tout, des symptômes de stress hydrique.

Tableau 2. Pluviométrie (mm) en 1987 à Gossi et en 1988 pour les autres localités

	Gossi	Timbajawen	Ebanguimellane	N'Daki
>20.6	39	0	0	12
21.6-30.6	6	0	3	4
1.7-10.7	8	17	19	16
11.7-20.7	11	9	8	20
21.7-31.7	7	31	22	42
1.8-10.8	11	53	81	85
11.8-20.8	16	87	15*	84
21.8-31.8	21	18	8	4
1.9-10.9	16	31	13	4
11.9-20.9	0	13	7	4
21.9-30.9	0	22	16	19
1.10-10.10	10	0	4	0
Totale mm	145	281	196	294

* observation incertaine

Le phosphore est considéré comme l'élément nutritif qui limite le plus les rendements au Sahel (Fussel et al. 1987). Bationo et al. (1989) ont estimé, dans les conditions sahéliennes, à 7,9 ppm selon la méthode de Bray P1 le niveau du phosphore dans le sol qui permet d'obtenir 90% du rendement maximal. La teneur en phosphore a été trouvée au-dessus de ce niveau dans les deux couches examinées à Gossi et dans la couche 40-60 cm à N'daki (tableau 3). Cependant, l'analyse du sol utilisée pour le phosphore dans cette étude a été celle de Bray 2. Lorsque ces deux méthodes furent comparées sur 30 différents sols au Nigeria, la quantité de phosphore extraite avec la méthode de Bray 1 et Bray 2 fut respectivement de 22,4 ppm et 27,1 ppm (Enwezor 1977) et la corrélation entre les deux méthodes fut élevée ($r^2 = 0,87$). Cela montre que ces deux méthodes sont proches l'une de l'autre. Il en suit que le besoin en phosphore semble être satisfait seulement à Gossi. Le pH n'a probablement pas limité les rendements dans ces essais, car le pH a été au-dessus de 5 sur tous les sites.

Les sols, où les essais furent menés, sont des sols bien sableux avec un pourcentage de sable d'environ 90% (tableau 3). Cela représente un niveau de sable normal pour ce type de sol au Sahel (Stroosnijder 1982, Spencer & Sivakumar 1987).

Tableau 3. Résultats des analyses des sols dans la couche 0-20 cm (1) et dans la couche 40-60 cm (2)

	Gossi		Ebanguim.		N'daki		Timbaj.	
	1	2	1	2	1	2	1	2
pH KCl	6,2	6,5	5,8	6,1	5,2	5,0	5,6	5,7
P (Bray 2) ppm	21,0	18,3	3,4	1,7	3,2	18,8	2,0	5,6
CEC mé/100 g	2,0	1,7	0,5	1,3	0,6	1,3	1,5	3,0
Sable %	89,3	88,0	92,5	90,2	91,9	90,0	89,5	86,3
Limon %	2,3	1,7	1,7	1,8	1,5	1,1	3,1	2,6
Argile %	8,4	10,3	5,7	8,0	6,6	8,8	7,5	11,1

CEC = «capacité de échange de cations»

RESULTATS

Les résultats obtenus à Gossi en 1987 ont montré un effet positif des billons sur la culture (tableau 4). L'apport de paille n'a pas contribué à augmenter les rendements. Les billons ont entraîné un développement plus rapide du mil au début du cycle, des rendements en grains et en paille plus élevés, et une augmentation de l'indice de rendement et du poids de 1000 grains. Il est étonnant qu'un rendement, toutefois faible, ait pu être obtenu avec une pluviométrie d'uniquement 63mm au cours de la culture.

Figure 1. Plante du mil tombée suite à une tempête de sable

Tableau 4. Résultats de l'essai à Gossi

	Levée %	Hauteur cm	Grains kg/ha	Paille kg/ha	Indice de rendement	Poids de 1000 gr.
Sans travail	95,8	25	4	80	4,5	1,9
Billon	99,3	42	147	663	18,2	5,0
Moyenne	97,5	34	76	372	16,9	3,5
ppds 5%	n.s.	4	135	252	9,3	1,6

Il s'est avéré que l'emplacement des poquets sur les billons a influencé l'établissement des plantes. Le premier semis fut effectué sur la crête des billons. La levée y a été bonne, mais les tempêtes de sable ont arasé les crêtes des billons, entraînant un déracinement des jeunes plantes (figure 1). Un nouveau semis fut réalisé dans les sillons, mais la levée a été rendue difficile par le comblement des sillons avec du sable. Le dernier semis, réalisé sur les flancs des billons a bien réussi, car, alors, les plantes ont été un peu protégées par la crête des billons, et l'ensablement des plantes a été peu important.

Les résultats obtenus en 1988 ont été moins clairs que ceux obtenus à Gossi en 1987 (tableau 5). On note, d'abord, que la levée a été inférieure avec le traitement «zai» qu'avec les autres traitements. Le rendement en paille le plus élevé a été obtenu avec la méthode de «butte». La tendance a été la même en ce qui concerne le rendement en grains, bien que ce résultat ne soit pas trouvé significatif.

L'effet des différentes méthodes de labour du sol sur l'humidité volumique dans le sol et sur la densité apparente du sol a aussi été étudié. L'humidité volumique a été faible quand l'échantillonnage a eu lieu et qu'aucune différence significative entre le différentes méthodes n'est apparue.

Tableau 5. Les effets des méthodes de labour du sol (moyenne pour 3 localités en 1988) sur les différentes paramètres

	Levée %	Hauteur de la tige cm	Grains kg/ha	Paille kg/ha
Hiliare	89,5	156	1013	1944
Butte	94,7	157	1110	2336
Labour à plat	95,6	152	851	1695
Billons	96,6	158	992	1949
Zai	83,3	150	943	1828
Moyenne	91,9	155	982	1960
ppds 5%	9,0	n.s.	n.s.	319
Interaction M*L[1]	n.s.	n.s.	n.s.	n.s.

[1] Méthode(M)*Localité(L)

En ce qui concerne la densité apparente du sol, il s'est avéré, en utilisant de chiffres de N'daki et de Timbajawen, que la densité apparente a été de 1,58 kg/dm^3 là où aucun labour n'a été effectué alors qu'elle a été de 1,46 kg/dm^3 dans les billons. Cependant, cette différence n'a pas été trouvée significative.

DISCUSSION

L'effet positif des billons sur les rendements en 1987 pourrait être attribué au fait que le terrain n'avait jamais été cultivé auparavant. Le sol semblait compact, avec une croûte à la surface. Des signes de ruissellement sont apparus après de grandes pluies. La raison principale pour laquelle les rendements se sont révélés plus élevés sur les billons que sur les parcelles sans labour est probablement due à une diminution de la densité apparente du sol suite au labour. Une baisse de la densité du sol de 1,5-1,7 kg/dm^3 à 1,2 kg/dm^3, suite à un labour du sol, a été, en effet, enregistrée sur un sol sablonneux à l'ICRISAT Centre Sahélien à Niamey (ICRISAT Centre Sahélien 1985). Il est possible de penser qu'un effet similaire se soit produit sur les billons à Gossi, permettant un bon développement racinaire. Il a aussi été observé, à Gossi, qu'une faible partie de l'eau stagnait dans les sillons après de grands pluies, améliorant alors vraisemblablement les conditions hydriques. Il est aussi possible que l'effet postif du labour du sol en 1987 peut être attribué à le fait que le sol était humid en 1987 quand le labour a eu lieu. Il a éte montré à l`ICRISAT Centre Sahélien à Niamey que la meilleure qualité du labour peut être obtenu quand le labour du sol est effectué dans un sol humide (Hoogmoed & Klaij 1990).

L'apport de paille n'a pas augmenté les rendements en 1987, et ce résultat ne concorde pas avec d'autres résultats obtenus au Sahel, qui montrent qu'un apport du paille, normalement, augmente les rendements (Fussel et al. 1987, Klaij & Hoogmoed 1989).

La pluviomètrie a permis un meilleur développement des plantes en 1988 qu'en 1987. La levée la plus faible en 1988 a été trouvée avec la méthode de «zai». Cela peut s'expliquer par un ensablement des trous (zai) qui a empêché la levée. La méthode de «zai» n'est donc pas adaptée aux conditions pedo-climatologiques du Gourma. En plus de la levée, l'effet des traitements a été trouvé significatif sur le rendement en paille. En 1988, ce furent les méthodes traditionnelles qui donnèrent le meilleur rendement en paille. La recherche dans d'autres parties du Sahel, a, en général, montré un effet positif du labour du sol (Charreau & Nicou 1971, Nicou & Charreau 1985, ICRISAT Centre Sahélien 1986, ICRISAT Centre Sahélien 1988, Fussel et al. 1987, Klaij & Hoogmoed 1989). En effet, le labour permet tout d'abord, un meilleur développement racinaire, du fait d'une baisse de la densité du sol et d'une augmentation de la porosité du sol (Nicou 1974, Chopart & Nicou 1976, Chopart 1983, Nicou & Charreau 1985). Ensuite, le labour du sol améliore le régime hydrique du sol par une diminution du ruissellement (Stroosnijder & Hoogmoed 1984, Nicou & Charreau 1985), et par une rupture du front capilaire (Nicou et Charreau 1985). Cependant, il a été montré que l'effet du labour reste limité, si aucun apport d'engrais n'est fourni (ICRISAT Centre Sahélien 1986, Fussel et al. 1987, Klaij & Hoogmoed 1989). Ceci aide à comprendre pourquoi le labour n'a pas augmenté les rendements dans l'étude réalisée ici, car les terrains expérimentaux de 1988 avaient une fertilité naturelle très faible, et aucun engrais n'a été apporté.

Il y a lieu de croire que la confection manuelle des billons au Gourma est une tâche hors de portée pour les cultivateurs, car le besoin de main-d'oeuvre est trop élevé. La traction animale s'avère donc nécessaire, mais l'introduction de la culture attelée risque de se heurter à d'autres problèmes, à savoir le mauvaise forme des animaux à la fin de la saison sèche, et le calendrier de travail serré en début de saison. Un labour préalable au semis retarde celui-ci, si le cultivateur utilise les premières pluies pour réaliser le labour.

Les résultats obtenus, la littérature citée, et les considérations apportées sur les difficultés attachées à l'introduction de la culture attelée au Gourma, permettent donc de conclure que, dans les conditions sosio-économiques actuelles, il est difficile de mettre au point une alternative aux techniques traditionnelles.

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Supplementary lighting of *Begonia* x *cheimantha* Everett

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Christmas begonia (*Begonia* x *cheimantha* Everett) was grown in greenhouses at three different locations (Ås, Kvithamar and Tromsø) in Norway at latitudes 59.5° 56'N, 63.5° 25'N and 69.5° 39'N, respectively. The plants were given supplementary lighting (SL) with high-pressure sodium lamps (Philips SON/T), fluorescent lamps (FL) or high-pressure metal halide lamps (Philips HPI/T) at irradiances of 7.5, 15 or 22.5 Wm^{-2} PAR. The light treatments commenced from the beginning (Ås location) or the end (Kvithamar or Tromsø location) of short-day treatment (SD) until flowering (10-15 open flowers per plant). Light treatments also included various periods (2, 4 or 6 weeks) of natural daylight (ND) or SL from the start of SD treatment. Supplementary lighting enhanced the time until variable flower bud, anthesis and marketing stage. The earliest marketing stage was reached with an irradiance of 7.5-15 Wm^{-2} at Ås, 15 Wm^{-2} at Kvithamar and 22.5 Wm^{-2} at Tromsø. Supplementary light was most important during the first 4-6 weeks after the start of SD treatment for early flowering and a high number of flowers. An early potting date (August/September) resulted in the shortest time to visible flower bud, anthesis and marketing stage compared with a medium (middle of September) or late (end of September) potting date. The number of flowers per plant was lowest at the late potting date. Taking the average of the three potting dates, the marketing stage for plants grown under supplementary lighting was reached 12 and 19 days earlier at Ås and Kvithamar respectively, compared with that for plants grown under natural daylight conditions. Supplementary lighting increased plant diameter, total plant height and the quality of the plants at marketing stage. The flower size was also improved by the light treatment, but at the Ås location the formation of cup-shaped flowers occurred at very high irradiance levels. The highest quality plants were obtained at about 7.5 Wm^{-2} at Ås, 15 Wm^{-2} at Kvithamar and 22.5 Wm^{-2} at Tromsø.
The type of lamp used had only a minor effect on plant growth and quality at Ås, but high-pressure sodium lamps were slightly more effective than the fluorescent lamps at Kvithamar.

Key words: Artificial light, *Begonia* x *cheimantha*, lamps, light levels, supplementary lighting.

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Begonia x cheimantha, Christmas begonia or Lorraine Begonia is a short-day plant (SDP), but the photoperiodic requirement for flower initiation is strongly modified by temperature conditions (Heide & Rünger 1985). At temperatures above 21.5°C, flower initiation takes place only in short days (SD), while at low temperatures (15.5°C) the plants are day neutral (DNP). For commercial production two different growing programmes are used.

1. Flower initiation is provided by low temperature treatment (about 15.5°C) which starts at the beginning of September. The production time from potting (July/August) to marketing stage (about 10 open flowers per plant) will be 24-28 weeks.

2. Flower initiation is provided by two weeks of SD treatment and at a rather high temperature (21-22.5°C) as recommended by Heide (1962). The production time will be 19-20 weeks when the plants are grown under natural light conditions in the southern part of Norway (latitude about 60.5°C). Under lower light conditions at higher latitudes, the production time may be longer and the quality of the plants poorer.

The effect of irradiance level on flower initiation and flower development in Christmas begonia has not been given much attention. It is evident that high light level conditions during SD treatment of SDP such as poinsettia (Fjeld 1982) and chrysanthemum (Cockhull 1984) are favourable for flower formation and plant quality.

The object of this study was to find the optimal irradiance level and the most efficient light source for supplementary lighting for early flower initiation and short production time of leaf-propagated Christmas begonias.

MATERIAL AND METHODS

Leaf-propagated plants (ca. 12 weeks old) of Begonia 'Nova' were obtained from a commercial propagator in Norway. The experiments were carried out at three different locations:

1. Ås, Agricultural University of Norway (59.5° 56'N)
2. Kvithamar, Kvithamar Research Station (63.5° 25'N)
3. Tromsø, The University of Tromsø/Holt Research Station (69.5° 39'N).

The plants were potted in 12 cm plastic pots at three different times as follows:

Location	Potting date		
	Date I	Date II	Date III
Ås	6 Sept.	15 Sept.	29 Sept.
Kvithamar	28 Aug.	14 Sept.	28 Sept.
Tromsø*	14 Sept.		

* Both 'Nova' and 'Astrid' were used.

All the plants at Kvithamar and Tromsø were pinched seven days after the potting date. Plants grown at the Ås location were left unpinched. The plants were given two weeks of SD (10 h) treatment for flower formation 15-17 days after potting. Before and after SD treatment, all plants were provided with continuous supplementary lighting until marketing stage.

The growing medium consisted of limed and fertilized peat moss (Floralux). The plants were given a complete nutrient solution at every watering. The nutrient solution contained (in ppm): 163N, 42P, 240K, 40Mg, 114Ca, 53S, 2.0 Fe, 1.1 Mn, 0.20 Cu, 0.30 Zn, 0.33 B, and 0.025 Mo, made from Superba 7-4-21, calcium nitrate and potassium sulphate. Subirrigation was used.

The plants were grown at the following temperature regimes:

- 21.5°C from potting date until 21 October (at Ås) or 26 October (at Kvithamar and Tromsø).
- 18.5°C from 21 or 26 October until 11 November (at Ås) or 5 December (Tromsø) or 15 December (at Kvithamar).
- The temperature was lowered to 15.5°C during the final growth period until marketing stage.

The CO_2 concentrations in the glasshouses were ambient (340 μll^{-1}) at Ås and Tromsø, and about 900 μll^{-1} at Kvithamar. The CO_2 enrichment at Kvithamar was provided by injecting pure liquid CO_2 into the glasshouse.

Chlormequat (Cycocel) was applied to all plants five weeks after potting date as soil drench, 50 ml per pot. A concentration of 5000 mgl^{-1} active matter was used.

This investigation included five experiments, two at Ås, two at Kvithamar and one at Tromsø.

Series 1, carried out at Ås, Kvithamar and Tromsø

Effects of irradiance level, lamp type and potting date

The day after potting, the plants were given supplementary lighting continuously with fluorescent lamps (Philips TL33) or high-pressure sodium lamps (Philips SON/T). High-pressure metal halide lamps (Philips HPI/T) were used at Tromsø. During the SD treatment a daily 10 h lighting period was applied. The irradiance levels of supplementary light were maintained at 7.5, 15.0 and 22.5 Wm^{-2} PAR. The control plants were grown under natural light conditions supplemented with a low irradiance of photoperiodic lighting (about 0.5 Wm^{-2} PAR) at Ås. No control plants were used at Tromsø (continuous night from late in November) and no day extension lighting was provided at Kvithamar.

Series 2, carried out at Ås and Kvithamar

Effects of duration and time of supplementary lighting

The plants were potted at three different dates as indicated earlier. The supplementary lighting was provided by high-pressure metal halide lamps (Philips HPI/T) at the Kvithamar location and by high-pressure sodium lamps (SON/T) at Ås. The irradiance level was kept at 7.5 Wm^{-2}. The following light treatments were given:

1. Two weeks supplementary lighting (2WSL), then natural light (ND).

2. Four weeks supplementary lighting (4WSL), then natural light (ND).
3. Six weeks supplementary lighting (6WSL), then natural light (ND).
4. Supplementary lighting until marketing stage (SL-control)
5. Two weeks natural light (2WND), then supplementary lighting (SL).
6. Four weeks natural light (4WND), then supplementary lighting (SL).
7. Six weeks natural light (6WND), then supplementary lighting (SL).
8. Natural light until marketing stage (ND-control).

The different light treatments commenced at the beginning of the SD treatment (2 weeks) of the plants at the Ås location, and at the end of the SD treatment at the Kvithamar location. After termination of the SD treatment, supplementary lighting was given continuously.

The experiments were carried out with two replicates and with seven plants per plot at Kvithamar and Tromsø and five plants per plot at the Ås location. The following observations were made:

- Number of days from potting date to visible bud, first open flower per plant (anthesis) and marketing stage (10-15 open flowers per plant).
- Height (cm) to the top of the leaves (leaf height) and to the top of the inflorescence (total plant height).
- Flower diameter, measured at right-angles.
- Plant quality. A scale from 0 (very poor quality) to 6 (excellent quality) was used at Kvithamar, while the scale at Tromsø ranged from 1 to 9.
- Number of flowers per plant at a fixed date.
- Different quality criteria of the inflorescence (see Fig. 1).

Observations were subjected to a two-way analysis of variance. The relationship between any variables was determined by simple correlation analysis. $p < 0.001$ ***, $p < 0.01$ ** and $p < 0.05$ * indicating 0.1%, 1% and 5% level of significance, respectively.

RESULTS

Series 1. Effects of irradiance level, lamp type and potting date

Flower initiation and flower development

<u>Ås location:</u> Supplementary lighting considerably enhanced the time to visible flower bud, anthesis and marketing stage (10 open flowers per plant) (Table 1). Irradiance levels of 15.0 or 22.5 Wm^{-2} did not produce visible flower buds and anthesis any earlier than with a 7.5 Wm^{-2} irradiance. Earliest marketing stage was obtained at 15.0 Wm^{-2} with SON/T lamps. However, there was a very small effect of lamp type on visible flower buds, anthesis and marketing stage.

<u>Kvithamar location:</u> Increasing the irradiance level from 7.5 to 15 Wm^{-2} reduced the time to marketing stage significantly ($p < 0.001$) from 87.5 to 81.8 days, respectively. An increase in irradiance to 22.5 Wm^{-2} resulted in a further non-significant reduction in the days to flowering (80.3 days).

Lamp type	Supplementary light level Wm⁻² PAR	Number of days to Visible flower bud	Anthesis stage	Marketing
TL33	7.5	46.4b	55.8b	67.7b
	15.0	44.3b	52.0b	64.6bc
	22.5	44.8b	52.4b	64.7bc
SON/T	7.5	45.0b	54.5b	67.4b
	15.0	42.6b	50.7b	61.8c
	22.5	43.5b	51.1b	62.9bc
ND (control)		55.4a	55.4a	79.7a

Table 1. Effects of supplementary lighting with fluorescent lamps (TL 33) and high-pressure sodium lamps (SON/T) on number of days to visible flower bud, anthesis (one open flower per plant) and marketing stage (10 open flowers per plant) of *Begonia x cheimantha* 'Nova' at location Ås. Values within the columns followed by different letters are significantly different at the 5% level according to Duncan's multiple range list. ND = natural daylight. Average of three potting dates

High-pressure sodium lamps compared with fluorescent lamps, had a significant ($p < 0.05$) reducing effect on the time to flowering from 84 to 82 days (as an average of the irradiance levels).

Tromsø location: Increasing the irradiance level increased the number of flowers per plant at every date of registration (Table 2). Time to marketing stage (10-15 flowers) was reduced from 76 days at 7.5 Wm^{-2} to 73 days and 69 days for the next two irradiance levels respectively. For lamp type or cultivars there was no significant difference in rate of flower development, and there was no significant interaction between lamp type and light level with regard to flower development.

Light level	Number of flowers after 69 days	73 days	76 days	80 days
7.5 Wm^{-2}	3.5	6.3	10.8	22.8
15.0 »	8.8	14.4	22.9	31.8
22.5 »	12.9	20.1	30.7	40.6
significance	**	**	**	**

Table 2. Effects of different irradiance levels on the development of flowers after a fixed number of days from potting (14 September) in *Begonia x cheimantha*. Tromsø location

The main effects of potting date on number of days to visible flower bud, anthesis and marketing stage are presented in Table 3. The earliest potting date (6 September at the Ås location) resulted in significantly earlier visible flower buds, anthesis and marketing stage compared with results from late potting dates (date II and III). At the Kvithamar location a shorter time to marketing stage was obtained with the late than with the early potting dates when only plants grown under supplementary lighting were included in the data (Table 3). The control plants, however, flowered after 92 days at the earliest potting date (date I) and after 98 days at date II. Plants from the latest potting date (date III) did not flower until the experiment was terminated after 100 days at the Kvithamar location. At Ås the control plants reached marketing stage after 69, 83 and

88 days at the early (date I), medium (date II) and late (date III) potting dates, respectively.

Table 3. Main effects of potting date on number of days to visible flower bud (VB), anthesis and marketing stage of *Begonia x cheimantha* 'Nova'. Average of four light levels at the Ås location and three light levels (without control plants) at the Kvithamar location. For statistical differences see Table 1

Potting date	Week no.	Number of days to VB Ås	Anthesis Ås	Marketing stage Ås	Marketing stage Kvithamar
I	35	39.2b	47.0b	58.8c	87.9c
II	37	50.2a	58.1a	72.7a	82.0b
III	39	48.5a	58.9a	69.4b	79.7a

Height, plant diameter and plant quality

Leaf height was not influenced by irradiance level (Table 4 and 5). Increasing the irradiance levels resulted in a slightly greater total plant height (only at the Kvithamar location) and plant diameter (Tables 4 and 5). The difference in plant diameter and total plant height between the non-illuminated control plants and the illuminated plants increased significantly ($p < 0.001$) as the irradiance level increased from 7.5 to 22.5 Wm^{-2} (data not shown).

Table 4. Effects of potting date, irradiance level and light source on plant growth and development of *Begonia x cheimantha*. Artificially illuminated plants only. Kvithamar location

Potting date Irradiance level Light source	Leaf height, cm	Total plant height, cm	Plant diameter, cm	Plant quality, 0-6, 6 best
28 August (I)	11.1	19.3	16.6	3.9
14 September (II)	12.3	21.4	17.0	2.8
28 September (III)	12.5	19.8	16.6	3.0
significance	***	**	ns	***
7.5 Wm^{-2}	11.8	19.3	16.2	3.0
15.0 Wm^{-2}	12.1	20.2	17.0	3.3
22.5 Wm^{-2}	11.9	21.0	17.1	3.4
significance	ns	*	*	ns
Fluorescent tubes	12.4	19.9	16.8	2.9
High-pressure sodium lamps	11.5	20.4	16.7	3.5
significance	*	ns	ns	**

High-pressure sodium lamps had a greater effect in reducing leaf height and improving plant quality compared with fluorescent lamps at the Kvithamar location (Table 4). However, lamp type had no influence on total plant height and plant diameter. At the Ås location lamp type had no significant effect on leaf and total plant height, plant diameter and plant quality. There was no significant interaction between lamp type and

	Plant height, cm		Peduncle height, cm	Plant diameter, cm	Plant quality 1-9, 9 best
	leaf height	total height			
Light level					
7.5 Wm^{-2}	14.3	18.6	4.3	18.3	4.8
15.0 "	14.9	19.2	4.3	19.6	6.8
22.5 "	15.4	19.6	4.2	20.4	7.1
significance	ns	ns	ns	**	**
Cultivar					
Nova	14.4	18.5	4.1	18.5	5.9
Astrid	15.4	19.7	4.3	20.3	6.5
significance	**	**	ns	**	ns

Table 5. Effects of irradiance level and cultivar on the plant development in *Begonia* x *cheimantha* potted 14 September - Tromsø location

irradiance level or lamp type and cultivars on the various growth parameters on plants grown at the Kvithamar location.

An early potting date resulted in more compact plants and better plant quality than late potting dates (Table 4).

The quality of plants grown at the Tromsø location (Table 5) was significantly improved by increasing the irradiance levels, and the best quality was obtained at a level of 22.5 Wm^{-2}. An irradiance level of 15 Wm^{-2} was required in order to increase plant quality significantly ($p < 0.01$) compared with plants grown under natural light at Kvithamar. At this location, some leaf scorce was observed at the highest light level. At Ås an irradiance level of 7.5 Wm^{-2} resulted in high quality plants (data not shown). The plant quality decreased when the potting date was delayed from early (potting date I) to late (potting date III) (Table 6). Similar results were observed in the experiment at Ås (Figs. 1 and 2). Without supplementary lighting the inflorescence became elongated and the number of flowers was low. This was most pronounced at the late potting date (Figs. 1 and 2). At Kvithamar a significant ($p < 0.001$) interaction between potting date and irradiance level was also found (Table 6).

Potting date	Natural light	Irradiance level, (Wm^{-2})		
		7.5	15.0	22.5
28 August (I)	3.1	3.5	3.3	4.8
14 September (II)	1.6	2.6	3.4	2.6
28 September (III)		2.9	3.1	3.0

Table 6. Effects of potting date and irradiance level on the plant quality of *Begonia* x *cheimantha* ranged from 0 to 6 (0 = poor quality and 6 = excellent quality) - Kvithamar location

Number of flowers, flower type and flower size

Potting date had a rather small influence on number of flowers per plant on 1 December at the Kvithamar location (Table 7). This indicates that late-potted plants had a more rapid flower development than early-potted plants. On the other hand, plants grown at Ås displayed a higher number of flowers per plant at the early (date I) than at

Figure 1. Effects of two potting dates and four irradiance levels on growth and flowering in *Begonia* x *cheimantha* 'Nova'. The potting dates were:

Upper row: 6. September (week no. 35)
Lower row: 29. September (week no. 39)

The irradiance levels were from left:

1 = 7.5 Wm^{-2} with TL 33 lamps
2 = 15.0 Wm^{-2}
3 = 22.5 Wm^{-2}
ND = natural daylight (control)

The photograph was taken on 10 December at the Ås location

the late (date III) potting date (Figs. 1 and 2). Increased irradiance levels resulted in a higher number of flowers when the irradiance was more than 7.5 Wm^{-2} (Table 7, Fig. 1). Lamp type had no significant influence on the flower number.

Potting date had a significant effect on the formation of female flowers (Table 7), but this was not attributed to light conditions since increasing irradiance levels had a

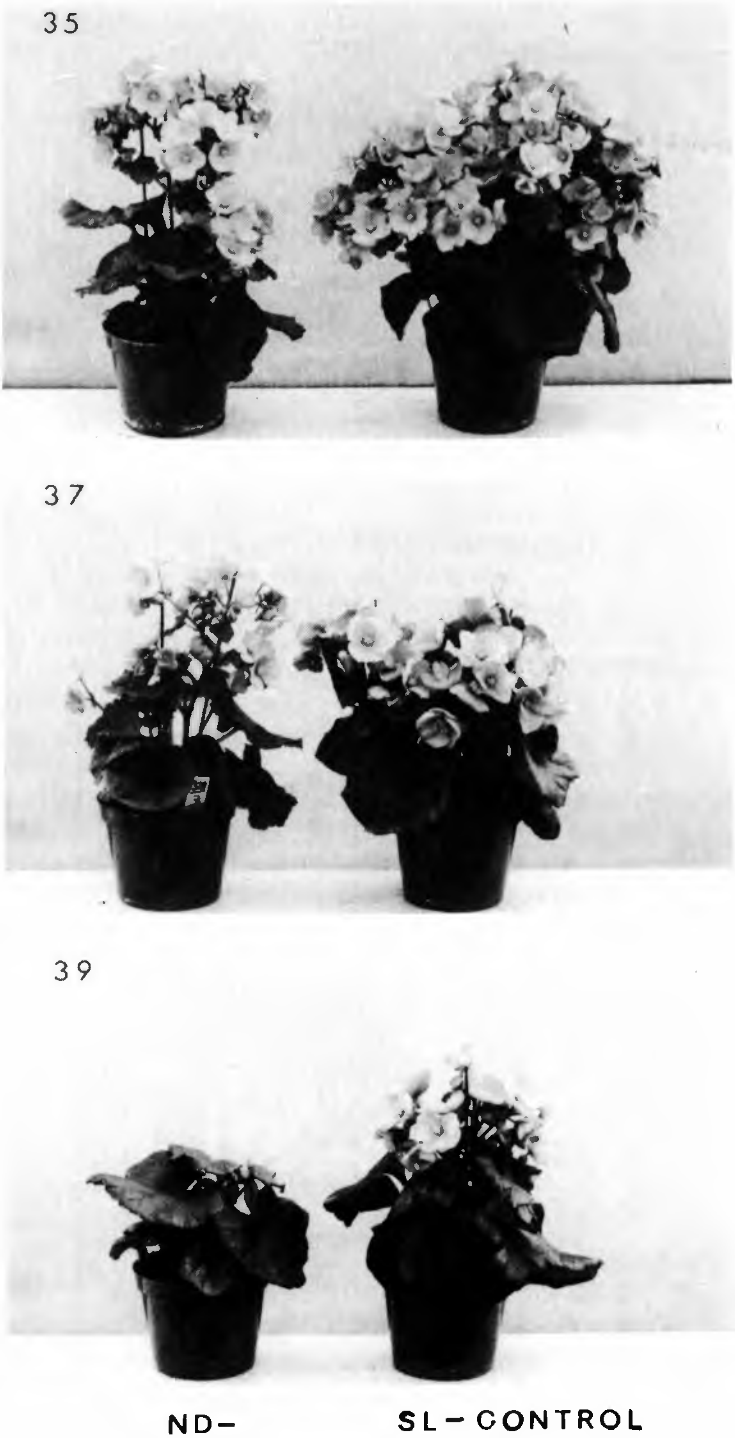

Figure 2. Effects of potting dates (weeks 35, 37 and 39 are indicated in the figure) and supplementary lighting (SL-control) compared with natural daylight (ND-control) on growth and flowering in *Begonia x cheimantha* 'Nova'. The photograph was taken on 10 December. Series 2 at the Ås location

Table 7. Effects of potting date and irradiance level on number of flowers per plant and percentage of female flowers in *Begonia x cheimantha* 'Nova'. The data were taken on 1 December - Kvithamar location

Potting date Light level Light source	Number of flowers	% ♀ flowers
28 August	23.1	18.0
14 September	21.9	11.8
28 September	20.1	3.7
significance	*	***
7.5 Wm^{-2}	15.0	12.1
15.0 Wm^{-2}	22.1	9.9
22.5 Wm^{-2}	24.6	9.2
significance	***	ns

non-significant influence on the percentage of female flowers. The lamp type had no influence on the formation of female flowers (data not shown).

The flower size was not affected by the potting date at the Ås location (data not shown), and only the latest potting date (28 September) at Kvithamar resulted in a significantly smaller flower diameter than was found with the earlier potting dates (Table 8). Supplementary lighting at a low irradiance level (7.5 Wm^{-2}) increased the flower size significantly compared with that of the control plants (Table 9). The effect was most pronounced for the second flower in both the first and second peduncle. At a very high irradiance level (22.5 Wm^{-2}) the flower size was reduced compared with that at lower irradiance levels (Tables 8 and 9), and most markedly so at the first potting date. Observations of flowers at Ås clearly showed that the number of cup-shaped flowers was significantly greater at a high irradiance level (22.5 Wm^{-2}) and early potting date, than at lower irradiance levels (7.5 and 15 Wm^{-2}) and late potting date. No cup-shaped flowers were found in plants grown under natural daylight conditions (data not given).

Table 8. Effects of potting date and irradiance level on flower diameter (in mm) of *Begonia x cheimantha* - Kvithamar location

Potting date Light level	The first peduncle 1st flower	 2nd flower	The second peduncle 1st flower	 2nd flower
28 August	50.5	48.8	49.6	47.3
14 September	50.9	49.1	49.5	48.1
28 September	47.3	44.2	46.2	44.0
significance	ns	***	***	***
7.5 Wm^{-2}	49.9	47.5	48.8	46.6
15.0 Wm^{-2}	49.9	47.8	48.7	46.7
22.5 Wm^{-2}	49.0	46.8	47.8	46.2
significance	ns	*	*	ns

Series 2. Effects of duration and the time of supplementary lighting

Flower initiation and flower development

Supplementary lighting enhanced the time to visible flower bud and anthesis significantly ($p < 0.001$, Table 10). The enhancement was most pronounced for late (date III) than for early (date I) potting date. Increasing the duration of supplementary ligh-

Artificial light level	The first peduncle		The second peduncle	
	1st flower	2nd flower	1st flower	2nd flower
0	47.5	44.7	46.8	44.2
7.5 Wm^{-2}	51.0	49.3	49.8	47.9
15.0 "	51.2	49.3	49.9	48.0
22.5 "	50.0	48.5	48.9	47.7
significance	**	***	**	***

Table 9. Effects of irradiance level on flower diameter of *Begonia x cheimantha*. Average of two potting dates (28 August and 14 September) - Kvithamar location

ting from 2 to 4 or 6 weeks from start of SD treatment reduced the time until visible flower bud and anthesis. In contrast, increasing the duration of natural light from 2 to 6 weeks delayed visible flower buds and anthesis (Table 10).

Table 10. Effects of various treatments with supplementary lighting (SL) with SON/T lamps and natural daylight (ND) on number of days to visible flower bud (VB), and anthesis of *Begonia x cheimantha* 'Nova' potted on three different dates. The light treatments were given from start of short days - Ås location

Light treatments		Days to VB Potting date			Days to anthesis Potting date		
		I	II	III	I	II	III
2 WSL -->	ND	43.2	56.1	57.9	51.1	64.6	68.6
4 WSL -->	ND	41.6	53.3	53.8	50.1	61.7	62.9
6 WSL -->	ND	41.8	49.3	51.5	49.2	58.9	62.9
SL-control		40.8	52.0	53.3	48.5	59.4	61.6
2 WND -->	SL	43.8	52.4	53.9	50.9	59.5	64.3
4 WND -->	SL	44.0	53.2	58.5	52.3	62.5	65.5
6 WND -->	SL	48.8	54.0	61.4	55.9	63.0	70.9
ND-control		46.7	57.8	63.4	60.7	67.3	78.3

WSL = Weeks with supplementary lighting
WND = Weeks with natural daylight

The number of days from potting to marketing stage was significantly ($p < 0.001$) delayed in plants grown under natural daylight conditions (Table 11). The longer the ND treatment, the later the marketing stage. Supplementary lighting enhanced the marketing stage, and the earliest marketing stage was found in the SL-control plants. These plants reached marketing stage 12 and 18.5 days earlier at the Ås and Kvithamar locations, respectively, compared with plants grown under natural daylight conditions (Table 11).

Height, plant diameter and plant quality
An increased period of supplementary lighting at the beginning of the cultivation period increased plant growth (Table 11). The diameter of the plants increased with increasing periods of supplementary lighting both at the beginning of and during the late phase of

Table 11. Effects of different treatments with supplementary lighting (SL) and natural daylight (ND) on number of days from potting date to marketing stage (MS), leaf height, total plant height, plant diameter and plant quality of *Begonia x cheimantha* 'Nova'. Average of three potting dates

Light treatments	Days to MS		Kvithamar			
	Ås	Kvithamar	Leaf height, cm	Total height, cm	Plant diameter, cm	Plant quality, 0-6, 6 best
2 WSL -> ND	75.0	93.1	10.4	19.3	14.1	1.8
4 WSL -> ND	73.2	87.9	11.1	19.1	15.3	2.9
6 WSL -> ND	72.4	85.6	12.4	19.8	15.9	3.1
SL-control	70.0	83.3	11.7	20.6	15.9	3.1
2 WND -> SL	70.6	85.1	10.8	19.4	14.4	2.6
4 WND -> SL	71.7	91.7	10.2	19.9	14.2	2.3
6 WND -> SL	73.8	95.0	10.9	19.9	13.0	1.4
ND-control	82.0	101.8	11.7	21.0	14.5	2.0
significance	***	***	***	*	***	***

WSL = weeks with supplementary light
WND = weeks with natural daylight

cultivation. The plant quality was also improved by supplementary lighting, and a period of six weeks with lighting (6 WSL → ND) resulted in a similar plant quality to that with supplementary lighting throughout the whole cultivation period (SL-control).

Flower number, flower type and flower size

Supplementary lighting increased the number of flowers (averaged over three potting dates) from 8.7 (ND-control) to 19.0 (SL-control) (Table 12). The light treatment was particularly critical for flower numbers during the first 4-6 weeks after the SD treatment. The number of flowers was also influenced by potting date (data not shown). There was no significant difference in flower number between the early (date I) and medium (date II) potting dates, with 19.6 and 18.5 flowers per plant, respectively. Plants from the late potting date had significantly ($p < 0.001$) fewer flowers per plant (9.0 flowers).

The percentage of female flowers increased when the duration of supplementary lighting was increased at the beginning of the cultivation period (Table 12). An early potting date resulted in a higher percentage of female flowers than with the later potting dates (data not shown).

The flower size increased as the period of supplementary lighting increased, but the effect was rather small (Table 12). The difference in flower size between SL-control and ND-control plants was non-significant at the first potting date. At the late potting date the flower size decreased significantly from 45.0 mm to 39.1 mm in plants grown under supplementary light and natural daylight, respectively.

Table 12. Effects of different treatments with supplementary lighting (SL) and natural daylight (ND) on number of flowers, percentage female flowers and flower size of *Begonia x cheimantha* 'Nova'. Average of three potting dates at the Kvithamar location

Light conditions	Number of flowers	% ♀ flowers	Flower diameter, mm			
			1st peduncle		2nd peduncle	
			1st flower	2nd flower	1st flower	2nd flower
2 WSL -> ND	12.3	4.9	47.1	44.5	46.3	44.0
4 WSL -> ND	13.7	8.0	48.7	45.9	47.8	45.6
6 WSL -> ND	21.2	8.5	48.9	47.5	46.8	45.8
SL-control	19.0	8.7	48.7	47.3	48.2	45.9
2 WND -> SL	16.6	5.5	50.2	47.9	49.1	47.6
4 WND -> SL	15.2	4.8	49.5	47.9	48.5	47.3
6 WND -> SL	11.1	5.8	48.9	46.7	48.6	46.5
ND-control	8.7	7.8	49.2	45.4	47.8	45.5
significance	***	**	*	***	**	***

WSL = weeks with supplementary light
WND = weeks with natural daylight

DISCUSSION

It is evident that supplementary lighting enhances the time to visible flower bud, anthesis and marketing stage in Christmas begonia. The light has a dual effect on flowering. It enhances both flower initiation and flower development. Similar findings are reported in other SDP such as chrysanthemum (Cockhull 1984) and poinsettia (Fjeld 1982).

The light requirement for rapid flower initiation and flower development is rather low. In the south of Norway (60.5°N) plants potted in mid-September will reach the marketing stage before Christmas without supplementary lighting, but supplementary light will increase the plant quality. At higher latitudes (65-70.5°N) supplementary lighting is required in order to reach marketing stage in good time before the Christmas sales. The total global radiation of 223 MJm^{-2} outside the glasshouse during the period from 14 September to Christmas (about 100 days) at the Kvithamar location did not provide enough natural daylight for production of high quality Christmas plants. The irradiance level of photosynthetic active radiation (PAR) of natural daylight at plant level inside the glasshouse (60% light transmission) was on average equal to about 8 Wm^{-2} with continuous irradiation. At the Ås location the natural daylight at plant level was equal to about 11.6 Wm^{-2} on average.

This indicates that supplementary lighting has to be applied at different levels according to the different locations (latitudes) if the total light demand is to be met. Results from this investigation show that the production period from potting date to marketing stage can be reached after 12 weeks provided there is proper supplementary lighting. In order to meet the total light requirement, the following approximate levels of supplementary lighting are recommended:

7.5 Wm^{-2} at Ås (about 60.5°N)
10 Wm^{-2} at Kvithamar (about 63.5°N)
15 Wm^{-2} at Tromsø (about 69.5°N)

Such a lighting programme will reduce the production time by about 7-8 weeks compared with a standard programme of 19-20 weeks where the plants are grown under natural daylight in the southern part of Norway (Heide 1962).

The effect of high irradiance levels with supplementary lighting is particularly important for plant quality at higher latitudes with low natural irradiance. Too high an irradiance level, however, may result in the formation of cup-shaped flowers and plants with leaf scorce. Such malformed flowers are symptoms of ethylene stress (Moe & Smith-Eriksen 1986). With a too low level of light, the flower diameter becomes smaller, while supplementary lighting increases the flower size. This is probably due to the greater support of assimilates (carbohydrates) to the flowers (Fjeld 1989). It is clearly shown that carbohydrate application to cut flowers of carnation enhances the growth of the petals (Halevy & Mayak 1981) and flower bud opening in Christmas begonia (Fjeld 1989).

The light source (lamp types) had no significant influence on flowering, but plant quality seemed to be slightly more improved under high-pressure sodium lamps compared with under fluorescent lamps. For economic reasons high-pressure sodium lamps are recommended for supplementary lighting. The larger number of female flowers at the early potting date compared with at the later potting dates may be a result of a higher average temperature during the growth period. Heide & Rünger (1985) reported that high temperatures and long days enhanced the formation of female flowers. Indeed, increasing the duration of continuous lighting resulted in a higher percentage of female flowers (Table 12).

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Effects of the period between pinching and the short day inductive phase on *Begonia* x *cheimantha* Everett

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Two cultivars of *Begonia x cheimantha*, 'Nova' and 'Hanne', were potted at two different dates and grown at different lengths of the pre-inductive vegetative period between pinching and the short day flower inductive phase. The vegetative part of the plants increased with increasing length of the pre-inductive vegetative phase, but flowering was delayed. Potting at the latest dates increased leaf area and reduced the occurence of female flowers. A period of about 12 days between pinching and the start of the short day treatment is recommended, with a somewhat shorter period for cultivars with large leaves, and possibly a slightly longer one for cultivars with small leaves.

Key words: *Begonia* x *cheimantha*, flowering, vegetative growth.

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Cultivation of *Begonia* x *cheimantha* Everett includes a vegetative period before the inductive short days. This period is necessary in order to build up a vegetative basis for further vegetative growth after flower induction.

In an intensive cultivation programme, every growth period has to be critically considered in relation to effectiveness. This investigation deals with an adaption of the vegetative period between pinching and the short day inductive phase. The purpose of an intensive programme is to combine effectiveness and high plant quality.

MATERIAL AND METHODS

The experiment, which was repeated over two years (1984 and 1986), was carried out in a double layer acrylic greenhouse and included rooted leaf cuttings of the cultivars 'Nova' and 'Hanne'. The potting dates in the first year were 28 August (week 35) and 14 September (week 37). The corresponding potting days for the second year were 29 August (week 35) and 11 September (week 37). The pot size was 12 cm. The plants were pinched 12-14 days after potting. Only the growth point was removed.

The pre-inductive phase (PIP) lasted for 4, 8, 12, 16 or 20 days with a 24 h day length. After the pre-inductive phase, the plants were submitted to a short day inductive phase (SDIP) lasting two weeks and with a day length of 10 h. For the remainer of the cultivation programme the day length was 24 h. The natural light was supplied by means of artificial light from high-pressure metal halide lamps (HPI-T), also used throughout the 10 h day flower induction phase (SDIP). The artificial irradiation was at 7.5 Wm^{-2} (PAR, conversion factor 2.8).

The temperature was set at 20-21°C day and night in the first experiment and 21-22°C in the second experiment (ventilation at 2°C above the set temperature), from potting to 26 October. From that time, the temperature was lowered to 18°C ± 0.5°C for the rest of the experimental period which lasted until 15 December.

Growth retardants were not used in the first experiment. In the second experiment, Cycocel (2-chlor-ethyl-three methyl three-methylammoniumchloride) in a concentration of 0.12% active matter was used. The plants were sprayed with Cycocel on two occassions, with an interval of one week shortly after the end of the inductive phase. CO_2 concentration was 600 vpm.

The nutrient solution contained (in ppm): 163 N, 42 P, 240 K, 40 Mg, 114 Ca, 53 S, 2.0 Fe, 1.1 Mn, 0.20 Cu, 0.30 Zn, 0.33 B and 0.025 Mo, made from Superba 7-4-21, calcium nitrate and potassium sulphate. Sub-irrigation was used. From the beginning of November the plants were allotted to their final area, 25 plants per square metre.

The experiment was carried out with two replicates and with seven plants per plot. The final registration of the plants was made on 15 December. The leaves were measured from the base of the petiole to the top of the leaf (height) and then at right-angles (width). The plant diameter was measured in two directions, right-angled. The number of open flowers also included withered flowers. The value of the plants was estimated by a score from 0 (poor quality) to 7 (very good quality).

Observations were subjected to a two-way analysis of variance. The relationship between any variables was determined by simple correlation analysis. $p < 0.001$*** $p < 0.01$** and $p < 0.05$* indicating 0.1%, 1% and 5% level of significance, respectively.

RESULTS

Plant growth

Increasing the PIP gave first of all a more vegetative plant (Tables 1 and 2). There was a significant ($p < 0.01$) interaction between cultivars and the PIP in Experiment 2, the cultivar 'Hanne' increasing in height with an increased PIP up to 12 days, while for 'Nova' there was no influence on height.

The leaf area increased when the PIP was extended (Table 2). In Experiment 1, the width of the leaves increased more than the leaf height of the two largest leaves. There was no significant interaction between cultivars and the length of the PIP with regard to the leaf size or the leaf ratio (width/height), (Table 3). The effect of a late potting date was more marked in Experiment 1 (Table 4) than in the second experiment. No significant interactions between potting date and cultivar were found.

An analysis of variance based on both experiments for 'Nova' showed a significantly ($p < 0.001$) increased height to the top of the leaves, but there was no significant effect

Table 1. Effects of the pre-inductive period (PIP) between pinching and the short day inductive phase (SDIP) on the growth of *B.* x *cheimantha* cultivars

Number of days in the pre-inductive phase	Exp. 1 'Nova'			Exp. 2 'Nova' and 'Hanne'		
	Plant height, cm		Plant diameter, cm	Plant height, cm		Plant diameter, cm
	to the top of the leaves	total height		to the top of the leaves	total height	
4	10.5	22.1	16.6	9.3	22.3	15.5
8	12.1	21.6	17.4	9.8	23.0	16.0
12	13.2	22.6	17.8	10.3	24.3	16.6
16	13.5	23.3	18.0	10.3	23.5	16.7
20	14.2	23.5	18.8	10.7	23.4	17.3
Significance	***	n.s.	***	***	*	***

Table 2. Effects of the pre-inductive period (PIP) between pinching and the short day inductive phase (SDIP) on the leaf size (mm) measured at right-angles, of *B.* x *cheimantha* cultivars.

Number of days in the pre-inductive phase	The leaf size in Exp. 1 'Nova'									The leaf size in Exp. 2 'Nova' and 'Hanne'					
	The largest			The 2nd largest			The 3rd largest			The largest			The 2nd largest		
	width	height	w/h	width	height	w/h	width	height	w/h	width	height	w/h	width	height	w/h
4	128	118	1.08	118	107	1.10	101	95	1.07	125	120	1.05	118	113	1.06
8	129	118	1.11	120	110	1.10	104	93	1.13	126	118	1.08	119	113	1.06
12	133	119	1.11	120	109	1.11	108	100	1.09	129	122	1.06	125	115	1.09
16	136	122	1.12	129	114	1.13	116	106	1.10	131	123	1.07	124	118	1.06
20	137	120	1.14	130	113	1.16	119	105	1.14	136	130	1.05	125	117	1.07
Significance	*	n.s.	**	***	*	**	***	**	**	***	***	n.s.	*	n.s.	n.s.

Table.3. Effects of cultivars and potting date on plant and leaf size of *B.* x *cheimantha* (Exp. 2)

Cultivar	Date of potting	Plant height, cm		Plant diameter, cm	The size of the two largest leaves, mm					
					The largest			The 2nd largest		
		to the top of the leaves	total height		width	height	w/h	width	height	w/h
'Nova'		10.8	24.7	17.4	140	132	1.07	136	126	1.08
'Hanne'		9.4	21.9	15.4	119	113	1.06	109	104	1.05
Significance		***	***	***	***	***	n.s.	***	***	*
	29 Aug.	10.2	23.0	16.4	128	120	1.07	120	112	1.08
	11 Sept.	9.9	23.6	16.4	131	125	1.05	124	118	1.05
	Significance	*	n.s.	n.s.	n.s.	*	n.s.	*	***	*

on total plant height when the PIP was increased. In the same way, the plant diameter increased significantly ($p < 0.001$) with increased PIP.

The date of potting affected plant development significantly (Table 5) as did the experimental year. A prolonged potting date resulted in a larger plant with bigger leaves. The width and the height of the two largest leaves increased significantly ($p < 0.001$)

Table 4. Effects of potting date on plant and leaf size of *B. x cheimantha* 'Nova' (Exp. 1)

Date of potting	Plant height, cm: to the top of the leaves	Plant height, cm: total height	Plant diameter, cm	The size (mm) of the three largest leaves: The largest width	The largest height	The largest w/h	The 2nd largest width	The 2nd largest height	The 2nd largest w/h	The 3rd largest width	The 3rd largest height	The 3rd largest w/h
28 Aug.	11.1	21.8	17.2	126	115	1.10	118	108	1.10	100	93	1.09
14 Sept.	13.6	23.1	18.0	136	122	1.12	127	113	1.13	114	104	1.11
Significance	***	n.s.	*	***	*	n.s.	**	*	n.s.	***	***	n.s.

for 'Nova' with increased growth period. For the largest leaf, the ratio between the width and the height of the leaf increased significantly ($p < 0.01$) with increased PIP.

Table.5. Effects of potting date and experimental year on plant and leaf size of *B. x cheimantha* 'Nova'

Potting time	Experiment	Plant height, cm: to the top of the leaves	Plant height, cm: total height	Plant diameter, cm	The size (mm) of the two largest leaves: The largest width	The largest height	The largest w/h	The 2nd largest width	The 2nd largest height	The 2nd largest w/h
Week 35 1)		11.0	23.0	17.3	131	122	1.08	126	115	1.10
Week 37 2)		12.1	24.1	17.7	140	128	1.10	132	121	1.10
Significance		***	**	*	***	**	n.s.	***	**	n.s.
	No. 1	12.7	22.6	17.7	132	120	1.11	124	111	1.12
	No. 2	10.8	24.7	17.4	140	132	1.07	136	126	1.08
	Significance	***	***	n.s.	***	***	***	***	***	**

1) Week 35 = 28 and 29 August
2) Week 37 = 11 and 14 September

A significant ($p < 0.01$) realtionship was found between plant height to the top of the leaves and the plant diameter in Experiment 2 ($r = 0.45$) and 'Nova' in both experiments ($r = 0.43$).

Flowering

As can be seen in Table 6, the number of flowers at a given time decreased with an increase in the number of days in the PIP. There was a significant ($p < 0.001$) interaction between cultivars and the length of the PIP for number of flowers. The cultivar 'Nova' had significantly ($p < 0.05$) more flowers than 'Hanne' on 1 December. Two weeks later, no significant difference was found. Potting the cuttings on 29 August, as compared with 11 September, significantly ($p < 0.001$) increased flowering on 1 December. On 15 December no significant difference in number of flowers was registered. The cultivar 'Nova', which had few open flowers (about 20) at the end of the experiment in the first year, had most flowers on the plants that were potted first (28 August).

For number of open flowers, there was a significant ($p < 0.001$) interaction between the length of the PIP and date of potting. On 1 December the number of flowers decreased from 32 to 23 when the PIP was increased from 4 to 20 days for plants potted

Table 6. Effects of the pre-inductive period (PIP) between pinching and the short day inductive phase (SDIP) on the number of flowers per plant and sex ratio of *B.* x *cheimantha* cultivars

Number of days in the pre-inductive phase	Exp. 1 'Nova'		Exp. 2 'Nova' and 'Hanne'		
	Number of flowers 15 December	Percent [1] ♀	Number of flowers 1 December	15 December	Percent [1] ♀
4	22	11.9	36	69	3.4
8	20	11.8	30	64	5.3
12	17	6.5	27	60	4.7
16	17	5.6	16	43	4.8
20	16	8.6	13	35	3.1
Significance	*	*	***	***	n.s.

1) Registered 15 December

in week 35 and from 39 to 3 for plants potted in week 37. Two weeks later, the number of flowers increased from 54 for plants grown with a PIP of 4 days to 61 flowers for plants with a growth period of 12 days, and then a decrease to 52 flowers with a PIP of 20 days. Plants potted in week 37 showed a gradual decrease in number of flowers per plant from 85 at the 4-day growth phase to 18 at the 20-day PIP.

Table 7. Effects of the length of the pre-inductive period (PIP) on the number of open flowers in *B.* x *cheimantha*

Cultivar	1 December Number of days in the PIP					15 December Number of days in the PIP				
	4	8	12	16	20	4	8	12	16	20
'Nova'	46	30	23	17	15	81	60	50	39	37
'Hanne'	26	30	30	16	11	58	68	70	47	34

The occurrence of female flowers was significantly ($p < 0.001$) different between cultivars. The mean proportion of female flowers for 'Nova' was 8.1%, and for 'Hanne' 0.4%. The proportion of female flowers was calculated on the same total number of flowers for both cultivars (no significant difference in number of flowers on 15 December). 'Nova' had 8.8% of female flowers in the first year and 8.1% the second year. This difference was significant ($p < 0.05$). Potting date also affected the sex ratio (Table 8), and a later potting reduced the occurrence of female flowers.

Plant quality

The subjective estimation of the plant quality at the end of the experiment showed the highest score when a 12-day growth phase was employed (significance $p < 0.05$). There was also a significant ($p < 0.001$) interaction between the length of the growth phase and potting time. Plants potted in week 35 gave the highest score when a 12-day growth phase was used. Potting the plants two weeks later resulted in the highest score after a growth phase of 8 days.

Table 8. Percentage of female flowers in *B. x cheimantha* as affected by different potting dates (named as week no.)

'Nova' (Exp. 1) Week no.			'Nova' and 'Hanne' (Exp. 2) Week no.			Exp. 2 'Nova' week no.		Exp. 2 'Hanne' week no.		
35	37	Sign.	35	37	Sign.	35	37	35	37	Sign. interaction
13.9	6.1	***	17.3	1.2	***	13.82	2.34	0.82	0.06	***

DISCUSSION

The results show that an adaption of the period between pinching and the start of the short day flower induction phase is of interest when producing *Begonias* in an intensive cultivation programme. This investigation does not give a fixed length for the period, but presents the effects of this pre-inductive phase.

An increased vegetative growth before flower induction is positive. The effect of the interaction between cultivars and the length of the pre-inductive phase on number of flowers may be related to a low flowering potential when the plants are submitted to a short vegetative phase. The lack of significant interaction indicates that the effects are rather stable. The results may be tranferred to other cultivars too. It is likely that a maximum length of the pre-inductive phase would give the consumers the most long-lasting flowering period.

Begonia cultivars differ in leaf size. The effect of the growth period on leaf size indicates that cultivars with large leaves should have a shorter vegetative phase than cultivars with small leaves.

The number of open flowers at the beginning of the flowering phase can be used as a basis for assessing the length of the cultivation period. The delay in flowering is somewhat less than the increase in the pre-inductive phase, but it is still of great significance and has to be taken into consideration when planning a cultivation programme. A recommendation for the length of the pre-inductive phase for an intensive cultivation programme could be put at 12 days. Cultivars with large leaves manage with a somewhat shorter period (minimum 8 days). With an intensive cultivation programme in mind, the period should not exceed 16 days, small-leaf cultivars included.

As has been shown by Moe et al. (1992), it is possible to produce flowering plants with a sufficient margin to Christmas when the potting takes place near mid-September. The negative effect of a later potting is first of all larger leaves. A positive effect registered was the reduction in the number of female flowers. The high incidence of female flowers in plants potted at the first dates may be related to a temperature effect (Heide 1969). A later potting reduced the high temperature cultivation period effect since the temperature was lowered in the middle of the cultivation programme.

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INSTRUCTIONS TO AUTHORS

THE MANUSCRIPT

The manuscript shall be typewritten on one side of the paper only. It shall be double spaced and have margins of at least three centimetres. Each of the following elements of the manuscript shall begin on a new page: (1) the title, (2) abstract, (3) the text, (4) summary, (5) list of references, (6) tables, (7) figure legends.

The pages shall be numbered consecutively beginning with the title page.

Articles will usually be organized as follows: (1) introduction, (2) materials and methods, (3) results, (4) discussion and (5) summary.

Up to three grades of headings can be used to divide up the text. Articles must not exceed 20 manuscript pages, and two copies should be submitted to the managing editor.

TITLE PAGE

The title page shall contain:

1. A precise but brief title. A subtitle may be used, but also this should be brief.
2. A short title of not more than 40 letters and spaces for use as a running headline.
3. The full names of all authors.
4. The name and adress of the institution and/or departments in which the research was carried out. Names of institutions shall be in English.

ABSTRACT AND KEYWORDS

Use only keywords listed in Agrovoc. The abstract must not exceed 150 words, corresponding to 10 lines in print. The abstract shall briefly describe the purpose/question of the experiment/research project, the method, results and the principal conclusions drawn. Use only standard abbreviations in the abstract.

Do not use more than 10 keywords and list them alphabetically.

Indicate the name and adress of the author to whom correspondence, proofs and offprints should be sent.

ACKNOWLEDGEMENTS

Acknowledgement shall be made only to persons who have contributed substantially to the results of the research. Authors are responsible for ensuring that individuals named are recognized as being identified with the results and conclusions described in the article.

TABLES

Each table shall be typed double spaced on a separate sheet of paper. They shall be numbered consecutively with Arabic numerals and have a concise descriptive heading. Abbreviations in tables shall be explained in footnotes, using the following symbols in this order: [1]), [2]), [3]), [4]), [5]).

Avoid horizontal and vertical rules (lines) in tables. Tables shall be self explanatory as far as possible without the reader having to refer to the text.

FIGURES

All illustrations, line drawings as well as photographs, shall be considered as figures. Figures shall be numbered consecutively with Arabic numerals. Letters, numerals and symbols must stand out clearly and be in relation to each other. Make sure they are large enough to take reduction. Before preparing line drawings the author should decide wether they are to be of 1 column, 1½ columns, or 2 columns with so that lettering, etc., after reduction, will be the same size on all drawings. Photographs should be submitted as near to their printed size as possible. If enlargement or reduction is significant in an photograph, the scale should be given on the back and not in the legend. The legend should make the general meaning comprehensible without reference to the text. Figure legends, shall be typewritten together on one or more sheets of paper.

REFERENCES

Reference indicators in the text will follow the Harvard style, with the author's name and the year of publication: Høeg (1971), or (Høeg 1971). The text reference indicator to a work by two authors is given by naming both authors: Oen & Vestrheim (1985) or (Oen & Vestrheim 1985). If three or more authors, the text reference indicator is given by adding et al. to the first named author: Aase et al. (1977) or (Aase et al. 1977).

In the list of references authors' names are listed alphabetically. Two or more works by the same author are listed chronologically and if published in the same year must be distinguished by the appendage a, b, etc. after the year of publication. The corresponding appendage must also appear in the text indicator.

Høeg, O.A. 1971. Vitenskapelig forfatterskap. 2. utg. Universitetsforlaget, Oslo. 131 s.

Oen, H. & S. Vestrheim 1985. Detection of non-volatile acids in sweet cherry fruits. Acta agriculturae scandinavia 35: 145-152.

Strømnes, R. 1983. Maskinell markberedning og manuell planting. Landbrukets årbok 1984: 265-278.

Uhlen, G. 1968. Nitrogengjødsling til ettårig raigras. Jord og avling 10(3): 5-8.

Aase, K.F., F. Sundstøl & K. Myhr 1977. Forsøk med strandrøyr og nokre andre grasartar. Forskning og forsøk i landbruket 27: 575-604.

Notice that:

- Only the first named author's initials and surname are inverted.
- The ampersand symbol is used between author's names.
- The date after the author's name is the year of publication.
- The issue number is given in parentheses after the volume number and only in cases where each issue of a particular volume begins on p. 1.
- A colon is used before page numbers in journal articles.
- The year of publication suffices in cases where the volume number is missing.
- In references to a book, the name of the publisher and the place of publication are given after the title of the book. If more than one edition of a book has been published, the edition used must be indicated. The number of pages should be given.
- It is recommended not to abbreviate the titles of periodicals, but in cases where this has nevertheless been done, abbreviations should be in accordance with the World List of Scientific Periodicals and/or BUCOP British Union Catalogue of Periodicals.

ABBREVIATIONS

Use standard abbreviations where available, otherwise abbreviations given in the text should be explained at their first mention. Quantities and units of measurement shall be in accordance with «Système International d'Unites» (SI).

PROOFS

Page proofs will be sent to the author for proofreading. They should be read immediately and returned to the journal's editorial office. Printer's mistakes should be marked with a blue pen and any possible changes made by the author against the manuscript in red. The second proof will be checked at the editorial office.

OFFPRINTS

An order form for offprints, plus price list, will be sent to authors along with the first proofs. The author(s) will receive 50 offprints free of charge. This form should be filled out and returned with the first proofs to the editorial office.

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