# Bolting variability in sugar beet
## *(Beta vulgaris L.)*

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ABSTRACT

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The variability of the bolting character in sugar beet is studied in the present work.

The results obtained show a wide variability which offers good prospects for breeding programmes.

The method of artificial production of bolting, which is described here, together with the speed of bolting can be considered to be a good system for this breeding work.

## INTRODUCTION

In the last few years there has been a sharp change in Spain, as far as location of sugar beet growing is concerned. In fact, while at the begining of the sixties 400.000 Tm of roots were produced in the Southern part of the country, the estimated figure for the 1976 season, is 4.000.000 Tm approximately.

The traditional growing season for this crop in the rest of the country, i. e. sowing in March-April and harvesting in October-December (spring sowing) is different from that in the South, where sowing takes place in October-November and harvesting in July-August (autumn sowing), in order to take advantage of the

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periods of maximum rainfall and to grow to a great extent in the dry land.

As sugar beet growing coincides with the mild winter in this area, the plant is subject to a number of days with vernalizing temperatures which satisfy in different degrees its cold requirements. This result in a certain amount of bolted plants when the long photoperiods occur.

This phenomenon causes various problems, which can be summarized as follows:

1. Loss in sugar content: NELSON and DEMING (1952) give results ranging between 5 and 14 % losses, WOOD and SCOTT (1975) between 5 and 7.5 %, and LONGDEN, SCOTT and TYLDESLEY (1975) 7 %.
2. Losses in root weight of about 7 % (LONGDEN *et al.*, 1975) but they can be much higher (NELSON and DEMING, 1952) up to 50 %.
3. Mechanical problems in harvesting, due to stems that block the machines, etc.
4. Problems in processing, due to fibrosity of bolted plants, which make manufacturing more expensive and difficult.
5. Seed shedding from the bolters, may cause problems of wild beets in later years.

In order to give an idea about the size of this problem, the percentages of bolters obtained with four different varieties in five consecutive years are shown:

| | *Year 1* | *Year 2* | *Year 3* | *Year 4* | *Year 5* |
|---|---|---|---|---|---|
| Var. 1 | 5.3 | 19.7 | 8.2 | 2.0 | 7.9 |
| Var. 2 | 8.1 | 15.7 | 10.7 | 2.2 | 10.1 |
| Var. 3 | 10.7 | 32.9 | 37.2 | 13.6 | 27.1 |
| Var. 4 | 0.0 | 3.1 | 1.8 | 1.1 | 1.8 |

We can notice two main causes of variation, i. e. the genetic constitution of the variety in respect to the bolting resistance, and the climatic conditions of each season.

Knowing the imporance of the problem, we decided to study the potential of bolting resistance in part of our material, along with a method of controlled bolting production which would allow us to take the maximum advantage of this potential and to fix effective selection coefficients, thus avoiding environmental interactions from year to year which make selection processes and testing difficult.

## MATERIAL AND METHODS

This work was carried out on 76 families and populations coming from 13 different origins. The number of entries from each origin, is shown in the results and it ranges from 1 to 25 according to the value of each origin in respect of other characteristics. None of the materials that we used had previously been subject to a selection for the bolting character.

The number of plants per entry is shown in the Table of results.

The method used is based on an incomplete and controlled artificial vernalization, thus avoiding environmental variations. Sowing is carried out in paper-pots Bh 313, which are kept in greenhouses at 20 °C during 30 days. After this time the plants have four true leaves, which seems to be a suitable stage for the begining of vernalization (MARGARA, 1960).

Then the plants are brought into a vernalizing room illuminated during 24 hours by means of incandescent bulbs, which provide an intensity of 550 lux at the plant level.

Basing ourselves on the results given by STOUT (1946) and CURTH (1955) and our previous results, the vernalizing temperature was 8 °C.

Two different periods were chosen for the cold treatment, 70 and 95 days. After these periods, the plants were moved into a greenhouse at 20-25 °C, illuminated during 24 hours with mixed light with intensity of 950 lux at the plant level, which is sufficient according to CURTH (1955) and WELLENSIEK (1964).

Bolting was controlled 15, 30, 45 and 60 days after planting.

## RESULTS

Table 1 shows the results obtained with cold treatment during 70 days.

TABLE 1.—*Bolting %.*

| | Plants | 15 d. | 30 d. | 45 d. | 60 d. |
|---|---|---|---|---|---|
| 16 — P 1 | 30 | 0,0 | 6.7 | 6.7 | 6.7 |
| 81 — P 1 | 65 | 29.2 | 61.5 | 72.3 | 78.5 |
| — P 2 | 60 | 25.0 | 53.3 | 73.3 | 73.3 |
| — P 3 | 54 | 31.5 | 63.0 | 85.2 | 94.4 |
| Av. | | 28.6 | 59.3 | 76.9 | 82.1 |
| 85 — P 1 | 81 | 38.3 | 54.3 | 71.6 | 86.4 |
| — P 2 | 68 | 35.3 | 41.2 | 77.9 | 80.9 |
| — P 3 | 51 | 35.3 | 66.7 | 92.2 | 94.1 |
| Av. | | 36.3 | 54.1 | 80.6 | 87.1 |
| 91 — P 1 | 30 | 20.0 | 23.3 | 36.7 | 50.0 |
| — P 2 | 22 | 4.5 | 59.1 | 59.1 | 63.6 |
| — P 3 | 16 | 0.0 | 37.5 | 62.5 | 68.7 |
| — P 4 | 28 | 7.1 | 14.3 | 25.0 | 32.1 |
| Av. | | 7.9 | 33.6 | 45.8 | 53.6 |
| 93 — P 1 | 59 | 5.1 | 13.6 | 28.8 | 37.3 |
| — P 2 | 79 | 6.3 | 15.2 | 35.4 | 35.4 |
| Av. | | 5.7 | 14.4 | 32.1 | 36.3 |
| 102 — P 1 | 64 | 45.3 | 75.0 | 75.0 | 89.1 |
| 409 — F 1 | 59 | 3.4 | 8.5 | 40.7 | 71.2 |
| 645 — F 1 | 24 | 8.3 | 62.5 | 79.2 | 87.5 |
| — F 2 | 33 | 75.8 | 90.9 | 97.0 | 97.0 |
| — F 3 | 32 | 50.0 | 93.9 | 100.0 | 100.0 |
| — F 4 | 41 | 29.3 | 61.0 | 82.9 | 95.1 |
| — F 5 | 27 | 74.1 | 88.9 | 96.3 | 96.3 |
| — F 6 | 30 | 66.7 | 93.3 | 100.0 | 100.0 |
| — F 7 | 29 | 44.8 | 75.9 | 96.5 | 96.5 |
| — F 8 | 33 | 57.6 | 81.8 | 87.9 | 87.9 |
| — F 9 | 27 | 29.6 | 81.5 | 100.0 | 100.0 |
| — F 10 | 34 | 38.2 | 82.4 | 97.1 | 97.1 |
| — F 11 | 30 | 53.3 | 86.7 | 96.7 | 96.7 |
| — F 12 | 36 | 44.4 | 86.1 | 94.4 | 94.4 |
| — P 1 | 61 | 80.3 | 85.2 | 100.0 | 100.0 |
| — P 2 | 64 | 82.8 | 89.1 | 95.3 | 95.3 |
| Av. | | 52.5 | 83.0 | 94.5 | 96.0 |
| 842 — F 1 | 29 | 82.8 | 96.6 | 100.0 | 100,0 |
| — F 2 | 36 | 69.4 | 86.1 | 97.2 | 100,0 |
| — F 3 | 11 | 63 6 | 90.9 | 90.9 | 90.9 |
| — F 4 | 31 | 61.3 | 96 8 | 96.8 | 96.8 |
| — F 5 | 29 | 41.4 | 75.9 | 96.6 | 100.0 |
| — F 6 | 32 | 59.4 | 71.9 | 90.6 | 90.6 |
| — F 7 | 37 | 45.9 | 86.5 | 91.9 | 91.9 |
| — F 8 | 32 | 75.0 | 93.8 | 100.0 | 100.0 |
| — F 9 | 32 | 71.9 | 87.5 | 100.0 | 100.0 |
| — F 10 | 36 | 47.2 | 80.6 | 100.0 | 100.0 |
| — F 11 | 32 | 34.4 | 65.6 | 87.5 | 90.6 |
| — P 1 | 96 | 75.0 | 97.9 | 100.0 | 100.0 |
| — P 2 | 77 | 44.2 | 79.2 | 96.1 | 100.0 |
| Av. | | 59.3 | 85.3 | 96.0 | 97.0 |

TABLE 1 (2). — *Bolting %.*

| | Plants | 15 d. | 30 d. | 45 d. | 60 d. |
|---|---|---|---|---|---|
| 7476 — P 1 | 26 | 34.6 | 50.0 | 92.3 | 92.3 |
| — P 2 | 28 | 14.3 | 46.4 | 82.1 | 100.0 |
| — P 3 | 31 | 19.3 | 51.6 | 80.6 | 83.9 |
| — P 4 | 30 | 16.7 | 50.0 | 93.3 | 93.3 |
| — P 5 | 38 | 34.2 | 71.0 | 94.7 | 100.0 |
| Av. | | 23.8 | 53.8 | 88.6 | 93.9 |
| 70491 — F 1 | 30 | 36.7 | 63.3 | 76.7 | 76.7 |
| — F 2 | 26 | 38.5 | 46.2 | 69.2 | 79.2 |
| — F 3 | 30 | 20.0 | 33.3 | 76.7 | 86.7 |
| — F 4 | 31 | 67.7 | 87.1 | 93.5 | 96.8 |
| — F 5 | 33 | 51.5 | 81.8 | 81.8 | 90.0 |
| — F 6 | 26 | 65.4 | 92.3 | 92.3 | 92.3 |
| — F 7 | 28 | 64.3 | 78.6 | 85.7 | 96.4 |
| — F 8 | 25 | 52.0 | 64.0 | 72.0 | 72.0 |
| — F 9 | 24 | 29.2 | 54.2 | 66.7 | 76.7 |
| — F 10 | 25 | 88.0 | 96.0 | 100.0 | 100.0 |
| — F 11 | 26 | 30.8 | 34.6 | 53.8 | 57.7 |
| — F 12 | 18 | 5.6 | 22.2 | 44.4 | 55.6 |
| — F 13 | 24 | 33.3 | 70.8 | 79.2 | 79.2 |
| — F 14 | 21 | 66.7 | 95.2 | 95.2 | 95.2 |
| — P 1 | 27 | 37.0 | 66.6 | 77.8 | 88.9 |
| — P 2 | 21 | 19.0 | 57.1 | 76.2 | 90.5 |
| — P 3 | 14 | 21.4 | 50.0 | 78.6 | 85.7 |
| — P 4 | 29 | 48.3 | 55.2 | 79.3 | 82.8 |
| — P 5 | 20 | 10.0 | 45.0 | 65.0 | 80.0 |
| — P 6 | 19 | 21.0 | 68.4 | 84.2 | 89.5 |
| — P 7 | 31 | 12.9 | 58.1 | 80.6 | 87.1 |
| — P 8 | 30 | 3.3 | 16.7 | 50.0 | 53.3 |
| — P 9 | 31 | 3.2 | 25.8 | 64.5 | 80.6 |
| — P 10 | 28 | 21.4 | 28.6 | 60.7 | 75.0 |
| — P 11 | 13 | 7.7 | 15.4 | 38.5 | 76.9 |
| Av. | | 34.2 | 56.3 | 73.5 | 81.0 |
| 71495 — P 1 | 22 | 4.5 | 31.8 | 77.3 | 86.4 |
| — P 2 | 27 | 7.4 | 59.3 | 96.3 | 96.3 |
| Av. | | 6.0 | 45.6 | 86.8 | 91.4 |
| 714102 — P 1 | 29 | 13.8 | 51.7 | 79.3 | 86.2 |
| — P 2 | 24 | 25.0 | 70.8 | 87.5 | 91.7 |
| Av. | | 19.4 | 61.3 | 83.4 | 89.0 |
| Average (76) | | 37.1 | 62.5 | 69.6 | 84.5 |
| Sd (76) | | 24.2 | 25.3 | 20.6 | 18.3 |

After 95 days of cold treatment the bolting rate was very high. A lot of variability was lost, in this case, as we can notice by observing the standard deviations of both treatments and each control

| | *15 d.* | *30 d.* | *45 d.* | *60 d.* |
|---|---|---|---|---|
| 70 d. cold | 24.2 | 25.3 | 20.6 | 18.3 |
| 95 d. cold | 18.6 | 16.5 | 16.3 | 15.7 |

On the other hand, the speed of bolting was very high, it was nearly definitive 15 days after trasplanting, and therefore could not be used as a variability source either. In Fig. 1, speeds of bolting in both treatmens are compared.

This is the reason why the results obtained with 95 days of treatment were not subsequently considered.

## DISCUSSION

Based on the results of Table 1, we have classified the 76 entries into 10 classes according to bolting percentages, between 0-10, 10-20, ... 90-100. With this classification we built the frecuency histogrammes that are shown in Fig. 2 for each of the four controls which were done. Similarly, the frecuency histogrammes of Fig. 3 show the means of the 13 different origins.

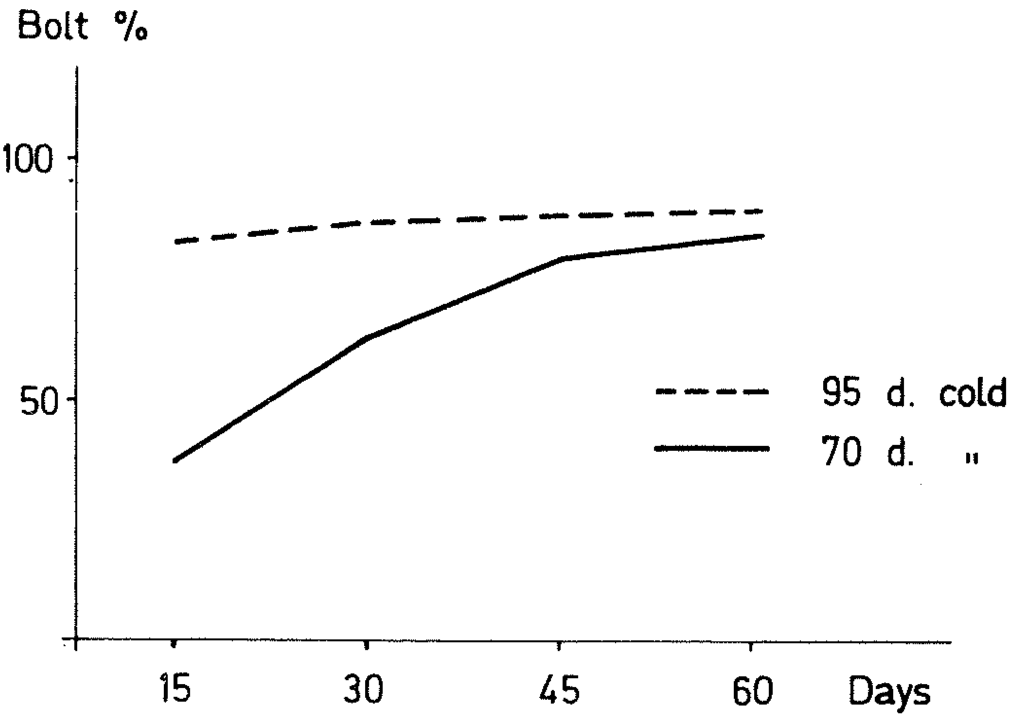


FIG. 1. Speed of bolting and length of the cold treatment.

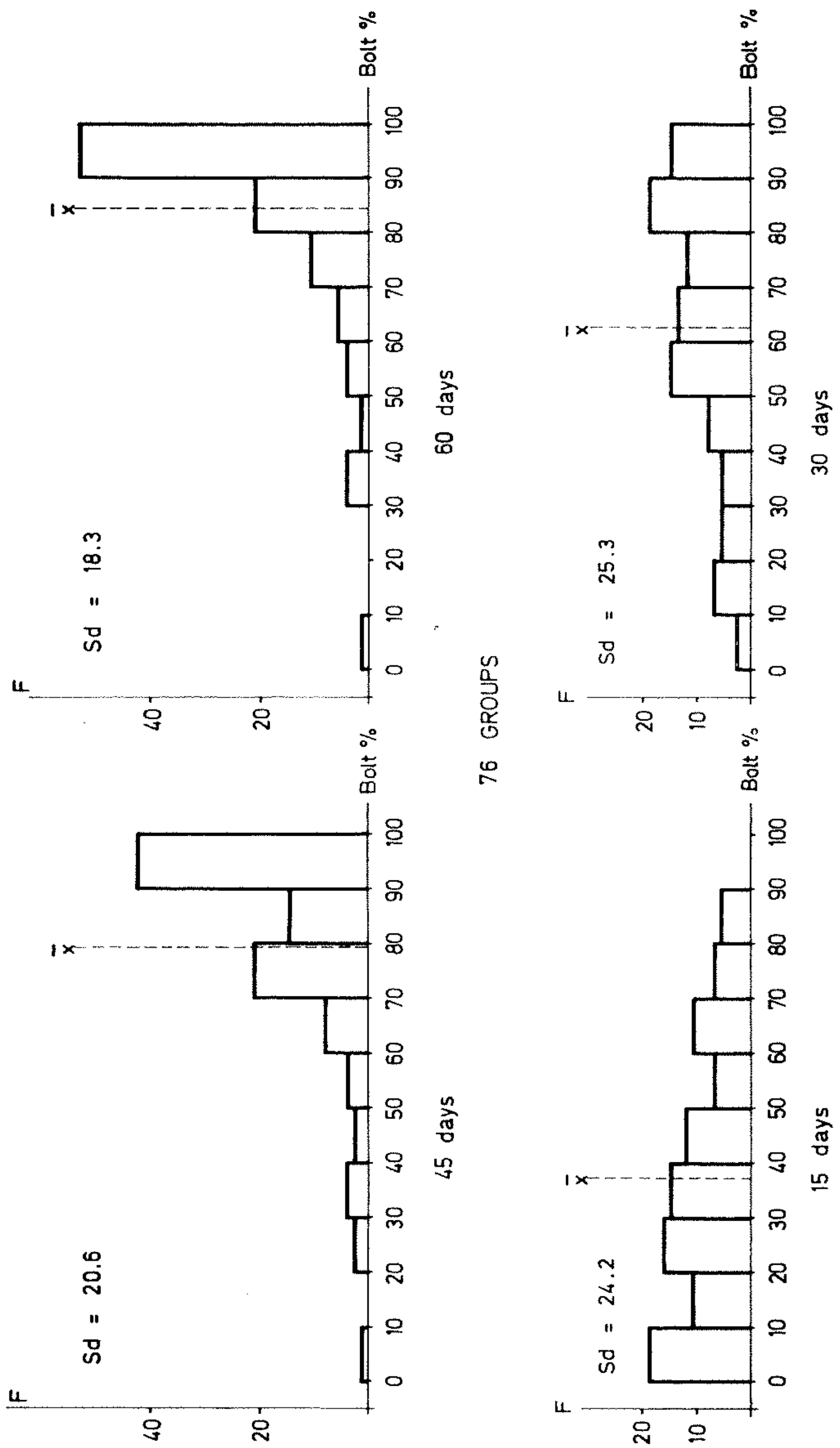
76 GROUPS
60 days
Sd = 18.3
45 days
Sd = 20.6
30 days
Sd = 25.3
15 days
Sd = 24.2
F
Bolt %
0 10 20 30 40 50 60 70 80 90 100
40
20
10

FIG. 2

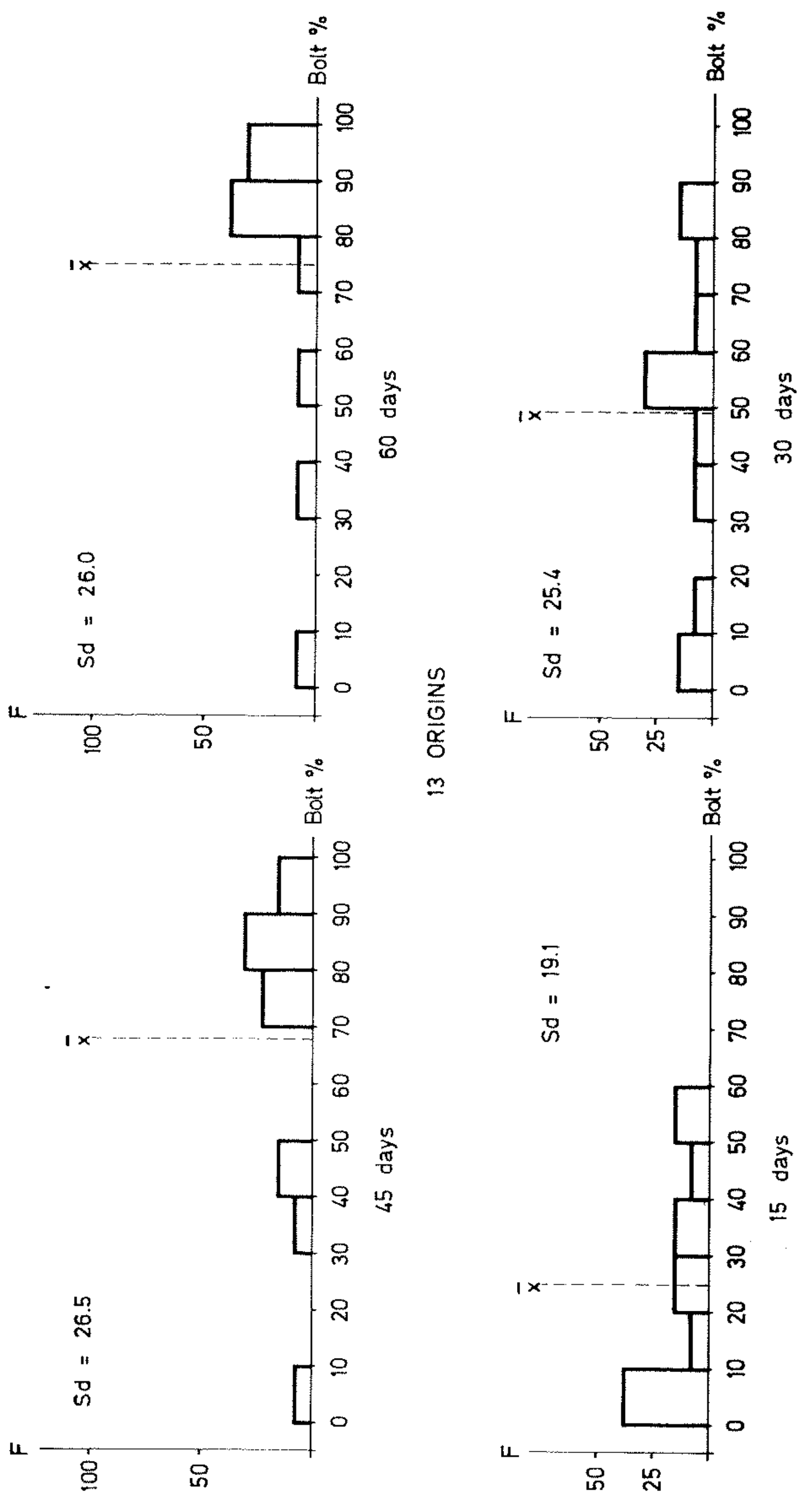
13 ORIGINS
Sd = 26.0
60 days
Sd = 26.5
45 days
Sd = 25.4
30 days
Sd = 19.1
15 days
Bolt %
F
100
50
25
0 10 20 30 40 50 60 70 80 90 100

FIG. 3

The first conclusion which may be derived from these histogrammes is the great variability which exists in the different breeding materials in respect of the bolting character. This shows that the genes which are responsible for resistance are not rare in nature, but rather frequent, and they therefore offer many possibilities of breeding for this character.

In the case of different origins we can notice that the control at 60 days offers a very wide variability range, which can clearly show the differences between materials. But if we consider the 76 groups individually, variability is higher in controls carried out at 15 and 30 days, due to the greater tendency to bolting in the most widely represented origins.

In order to test the possible usefulness of the analysis of speed of bolting, the correlation coefficients between early and late bolters were estimated, and the results obtained were the following:

*15 days with 60 days*

Origins (13) ———————— r = 0.6706 *
Total (76) ———————— r = 0.6019 **

* — 1 %
** — 0,1 %

*30 days with 60 days*

Origins (13) ———————— r = 0.8115 **
Total (76) ———————— r = 0.7888 **

These results indicate that the speed of bolting could be used for testing and selections.

Fig. 4 shows the frecuency histogrammes of the three origins which are most widely represented ,AD-645 with 12 families and 2 populations, AD-842 with 11 families and 2 populations, and AD-70491 with 14 families and 11 populations. We can observe that the tendency to bolting is very high in AD-842 with very few possibilities for breeding; AD-645 is a rather similar case, although the control of 15 days might be useful in repeated selections. However, we can notice that AD-70491 offers many short term possibilities starting from screenings at 30 days.

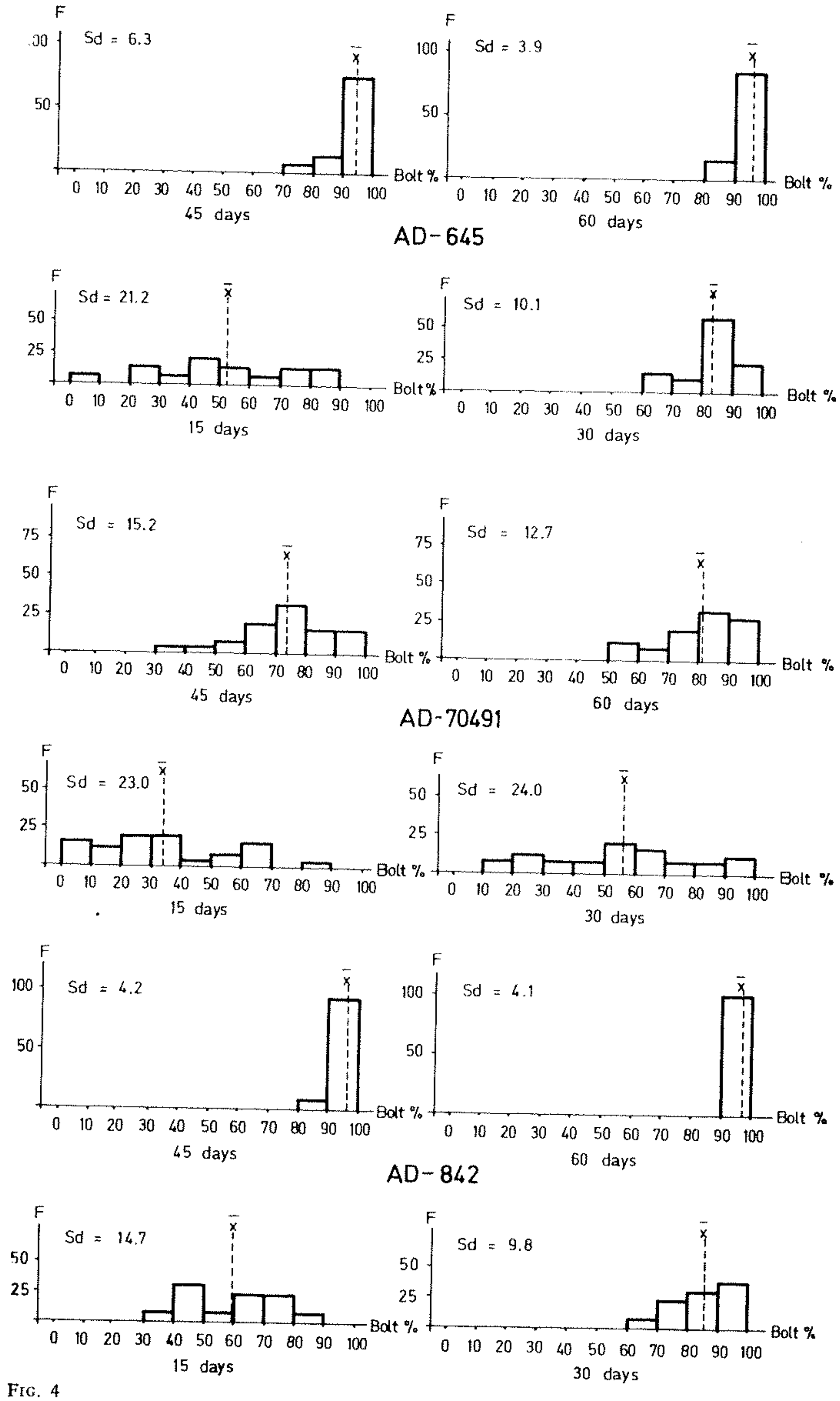
F
Sd = 6.3
Bolt %
45 days
F
Sd = 3.9
Bolt %
60 days
AD-645
F
Sd = 21.2
Bolt %
15 days
F
Sd = 10.1
Bolt %
30 days
F
Sd = 15.2
Bolt %
45 days
F
Sd = 12.7
Bolt %
60 days
AD-70491
F
Sd = 23.0
Bolt %
15 days
F
Sd = 24.0
Bolt %
30 days
F
Sd = 4.2
Bolt %
45 days
F
Sd = 4.1
Bolt %
60 days
AD-842
F
Sd = 14.7
Bolt %
15 days
F
Sd = 9.8
Bolt %
30 days

FIG. 4

## CONCLUSIONS

The conclusions one may derive from the present work can be summarized as follows:

1. The bolting resistance character shows a wide natural variability, which seems to indicate the relatively high frecuency of resistance genes.
2. The method of artificial producion of bolting which is described here, may be very useful to point out the existing variability, in breeding programmes and material testing.
3. The «speed of bolting» character shows a high correlation with final bolting, which make it interesting for breeding programmes and screening purposes.
4. The populations and families which were studied offer good possibilities to obtain bolting resistance.

## RESUMEN

Se presenta un estudio sobre la variabilidad del carácter espigado en remolacha azucarera. Los resultados obtenidos, indican una amplia variabilidad natural, que ofrece buenas perspectivas para los trabajos de mejora.

Se describe un método de producción artificial de espigado, de buena utilidad para estos trabajos, así como correlaciones con el carácter velocidad de espigado.

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