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# Gene-ecological Investigations in *Pisum* Mutants

## Part 2: Comparative Performance in Germany and North India

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**Summary.** Six mutants and nine recombinants of *Pisum sativum* were grown along with the mother variety at Kurukshetra, North India. The findings obtained were compared with those obtained for the same material grown at Bonn, Germany. The following observations were made.

Stem length and degree of branching are influenced differentially in the various genotypes tested in India as a consequence of a specific reaction of the genes to the climatic conditions. A gene for weak stem fasciation and gene *efr* for earliness in a specific gene combination are unable to express their action in North India whereas they are fully active in Germany. Furthermore, in Kurukshetra early flowering of some recombinants does not result in early ripening because their seeds require about double the time for full ripening than those of the mother variety.

At Kurukshetra, recombinant R 674A proved to be highly heat susceptible. All the plants died in early stages of ontogenetic development. Four other genotypes died due to heat before completing seed ripening. One mutant and three recombinants were found to be more tolerant to powdery mildew attack than the mother variety and Indian local lines. The seed production of eight genotypes in relation to that of the initial line was essentially better in North India than in Germany. They are obviously better adapted to the semi-arid conditions. Some of them appear to be useful for pea breeding in India. In contrast, a fasciated mutant, high yielding in Germany, is not able to express this potentiality at Kurukshetra. At Udaipur (Rajasthan, Western India), this mutant is unable to flower. Another four genotypes, tested at both Indian locations, exhibited an essentially poorer seed production at Udaipur than at Kurukshetra due to some ecological factors.

The findings indicate a specific response of some of the genotypes tested to the specific ecological conditions of the three locations, their response differing from that of the mother variety demonstrating thereby a different adaptational optimum.

**Key words:** Gene-ecology – Fasciated mutants – Penetrance – Flowering behaviour – Seed production

## Introduction

Usually, the behaviour of mutants is compared to that of their mother varieties under those environmental conditions in which they have been developed. There is an increasing number of examples which demonstrate that mutants can have adaptational optima different from those of their initial lines and can be thus superior to them under distinct ecological conditions. The best way to study the ecological reaction of mutants is by cultivating them under the controlled conditions of a phytotron. This has been successfully done with barley mutants in Sweden (Dormling et al. 1966; Dormling and Gustafsson 1969; Gustafsson and Dormling 1972; Gustafsson et al. 1973a, c, 1974, 1975). In this way, the impact of distinct climatic factors such as temperature, photoperiod, light quality amongst others that influence the specific traits of the genotypes tested can be singled out.

Another possibility for testing the ecological reaction of mutant genes is to grow them in locations having diverse climatic conditions. This has been done for small groups of *Pisum* mutants and recombinants of our collection which were cultivated along with the mother variety in Germany, Egypt, Ghana, Uganda, Brazil and in five climatically different regions of India. Drastic differences in the behaviour of some of these genotypes in relation to that of the initial line were found with regard to stem architecture, flowering and ripening time, seed and pro-

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tein production, tolerance to heat, drought and diseases (Gottschalk and Patil 1971; Gottschalk and Kumar 1972; Gottschalk and Imam 1973; Gottschalk and Kaul 1975; Müller 1975; Wolff 1975; Gottschalk 1976, 1978a; Müller and Gottschalk 1978; Gottschalk and Müller 1979). Investigations on the response of *Pisum* mutants to diverse ecological conditions have also been carried out in Russia (Sidorova and Uzhintzeva 1969; Sidorova et al. 1972; Sidorova and Bobodzhanov 1977).

The aim of the present investigation was to select some more mutants and recombinants of our *Pisum* collection which differ in their ecological reaction from the mother variety. For this purpose, six mutants and nine recombinants were cultivated along with the initial line in the district Kurukshetra of Haryana, North India. The climate of this region is semi-arid with hot and dry summers and moderately cool winters. Different traits which characterize the response of the genotypes to the climatic conditions were evaluated and compared to the corresponding findings obtained for the same material grown at Bonn.

## Materials and Methods

The following X-ray induced mutants of the variety 'Dippes Gelbe Viktoria' of *Pisum sativum* utilized exhibit the below given traits when grown in Bonn:

- 33B: Internodes feebly shortened, stem linearly fasciated.
- 37C: Phenotypically like the initial line but more branched and regularly higher yielding; a micromutant.
- 39: Slightly altered leaflet shape; a micromutant.
- 85A: Large leaves, strong grey-spotting on leaflets and stipules.
- 250A: Strong stem fasciation, tall, late, small grains, high yield; homozygous for about 15 mutant genes.

The following recombinants, homozygous for several mutant genes, were incorporated in the present investigations:

- R 605: Longer internodes, stem linearly fasciated, not late, slightly reduced chlorophyll content. Selected in $F_2$ of the cross of mutants 489C (strong stem fasciation) × 94A (abnormal flowers).
- R 667: Longer internodes, stem linearly fasciated, not late. From the cross of mutants 489C (strong stem fasciation) × 169 (chlorophyll deficiency).
- R 839: Longer internodes, non-fasciated, normal leaves, earlier than the initial line. From the intercross of the three leaf mutants *acacia*, *afila*, and Blixt's *cochleata* 5137.
- R 848: Longer internodes, stem strongly fasciated, narrow leaves, very late. From the cross of the two fasciated mutants 489C × 123.
- R 849: Longer internodes, stem linearly fasciated, large round stipules, slightly reduced chlorophyll content, early flowering. From the cross of mutants 46C (earliness) × 489C (strong stem fasciation).
- R 852: Longer internodes, non-fasciated, normal leaves. From the cross of mutants 489C (strong stem fasciation) × Blixt's *cochleata* 5137 (reduced stipules).
- R 853: Longer internodes, stem feebly fasciated, normal leaves, earlier than the mother variety. From the cross of the mutants 489C (strong stem fasciation) × Blixt's *cochleata* 5137 (reduced stipules).
- R 878: Short internodes, broad round stipules, early flowering. From the cross of mutants 2641 (short internodes) × 46C (earliness).
- R 879: Stem dichotomously bifurcated with high penetrance of the gene, early flowering. From the cross of mutants 1201A (stem bifurcation, reduced penetrance) × 46C (earliness).

The material was grown along wire fences during winter 1977/78 at Kurukshetra, North India along with the mother variety. 30 to 50 plants per genotype were evaluated with regard to:

- shoot height and internode length,
- degree of branching,
- days to flower and days for seed ripening,
- susceptibility to heat and mildew attack,
- number of pods per plant, seeds per pod and seeds per plant,
- thousand grain weight,
- yield per plant in grams.

The same material has been cultivated at Bonn for many generations in the form of 4 to 6 replications per genotype per year with 50 plants per replication (Fig. 1). All the values obtained are related to the corresponding mean values of the mother variety 'Dippes Gelbe Viltoria' grown in the same year at the same location.

## Results

The material grown in North India shows striking differences from that grown in Germany with regard to many of the traits studied. As the main aim of our investigations consists in testing the ecological reaction of the genotypes, the relative values related to those of the mother variety, not absolute values, are of interest. In the following section some traits which are specifically influenced by environmental factors are discussed.

### *Shoot Height*

Shoot height is a quantitative trait controlled by many genes of the genome and influenced by the environment. This becomes clear from the comparison of the stem length values obtained at Bonn and Kurukshetra for each genotype.

The climatic differences between Germany and North India induce significant alterations in even the initial line. The mean values for the stem length vary between 75 and 82 cms at different locations in Bonn whereas the corresponding value at Kurukshetra was 122 cms. In comparison to the mother variety, only three genotypes showed the same behaviour in Germany and India (the short-stemmed genotypes 33B and R 878 and the long-stemmed recombinant R 848). With regard to the other types tested, two groups can be distinguished. In one group, a ten-

dency to shorten the internode length under North Indian climatic conditions becomes discernible. The mutants 39 and 85A and the recombinant R 879 have the same stem length as the initial line when grown in Bonn. At Kurukshetra, however, they are 37 or 27% shorter, respectively. This also holds true for five long-stemmed genotypes which exhibit a strong tendency to shorten at Kurukshetra relative to the initial line. Recombinants R 605, R 667 and R 839, for instance, are about 35% longer than the mother variety at Bonn. These at Kurukshetra are similar to the initial line. The plants of recombinant R 853 are about 25% longer at Bonn, while at Kurukshetra they are 25% shorter than those of the mother variety. In the second group, the opposite reaction is observed. For instance, the relative plant height of mutants 37C and 150A and of the recombinant 849 is 15-20% greater at Kurukshetra than at Bonn.

These findings demonstrate that the reaction of the genotypes to the differences in the ecological conditions is not always uniform. On the contrary, each genotype shows a specific reaction on the basis of which the three groups mentioned above could be differentiated.

### *Branching*

The mother variety of our mutants shows a very low degree of branching when grown in Germany under the usual dense planting conditions (5 cms plant to plant distance along wire fences). Occasionally, lateral branches are formed, some of which develop seeds. This seed formation, however, is so late that they do not participate in the actual seed production of the plants. This also holds principally true for the majority of the mutants and recombinants of our collection.

At Kurukshetra, an essentially higher degree of branching occurs already in the initial line. Some mutants and recombinants exhibit still a higher degree of branching which is responsible for their increased seed production. Some examples may elucidate this situation more clearly.

Mutant 37C has arisen due to a micromutation which does not influence the plants phenotypically. In Germany, nearly all the plants of this genotype develop two equivalent stems which are equally efficient in seed production. That is the reason why the mutant had an increased seed yield in each generation tested so far. This feature becomes essentially more pronounced at Kurukshetra. The mean value for the character 'seed producing stems per plant' was 3.15 whereas the corresponding value of the mother variety was 1.60. Because of this high degree of branching, the number of pods per plant is highly increased, giving a seed production of about 70% more than that of the initial line. A similar situation is valid for the linearly fasciated recombinant R 667. In other cases, the high degree of branching does not lead to the expected increase of pod formation. For instance, the strongly fasciated recombinant R 848 has 2.75 stems per plant on an average but the number of pods is lower than that of the mother variety. This negative feature is counterbalanced by a similar increase of the number of seeds per pod resulting in a grain production at par with the mother variety.

### *Stem Fasciation*

Stem fasciation in our radiation induced *Pisum* mutants is controlled by four different genes which exhibit either an epistatic or an hypostatic behaviour (Gottschalk 1977). All these genes are present in mutant 489C which was used as one of the parents for developing the fasciated recombinants tested at Kurukshetra. Mutant 489C exhibits pronounced stem fasciation in North India but most of the plants of this genotype are not able to produce flowers. The very few that do produce flowers are unable to bear seeds. Thus, this mutant, high-yielding under Middle European conditions, is without any economic value in India. A few other fasciated genotypes were tested in order to ascertain their breeding value.

Mutant 250A is completely identical with 489C when grown in Germany. The plants are long, strongly fasciated, late flowering and ripening, small seeded and high yielding. $F_1$ hybrids from crosses between 489C and 250A are phenotypically identical with the parental mutants and there is no segregation in $F_2$. Thus, it was assumed that these two mutants are identical. This interpretation, however, has to be altered in the light of the findings obtained at Kurukshetra. The plants of mutant 250A exhibited a luxuriant flowering. They flowered about two weeks later than the mother variety; their small seeds required 12 days more for full ripening. Their seed production (number of seeds per plant) was about 12% less than that of the control material. If we consider the strongly reduced seed size, a mean value of only 43% of the control value for the character 'seed weight per plant' was obtained. The decisive point, however, is the fact that mutant 250A is at all able to flower, fruit and seed under the North Indian climatic conditions. This is in sharp contrast to mutant 489C. This differential behaviour is evidence that the two mutants are non-identical genetically. Their genes for stem fasciation are obviously multiple alleles.

The second fasciated mutant tested presently, no. 33B, is shorter than the mother variety. Its fasciation is very much pronounced at Kurukshetra but, in contrast to the usual situation of fasciated mutants, the number of pods per plant is not increased. Instead, the number of seeds per pod is highly increased which leads to its enhanced seed production (73% more than the mother variety). The potential productivity of this genotype gets somewhat reduced due to the reduced seed size.

The fasciated recombinants tested presently have been selected in the $F_2$ generation after crossing the fasciated mutant 489C with non-fasciated mutants of our collection. Thus, the genes for stem fasciation in those recombi-

nants are derived from 489C. In contrast to mutant 489C, they show good seed yielding properties in North India. For instance, the plants of recombinant R 667 are long, linearly fasciated and their flowering time is similar to that of the mother variety when grown in Germany. At Kurukshetra, they flower 9 days later and need about 7 weeks more for seed ripening. Their yield is essentially higher (see below). A similar situation is valid for the fasciated recombinants R 605 and R 849, the latter one will be discussed in the section 'flowering and ripening time'. Recombinant R 848 exhibits a similar behaviour but its seed production is essentially lower than that of the other fasciated recombinants tested in India.

An interesting gene-ecological behaviour is shown by the recombinant R 853. When grown in Germany, its long-stemmed plants show a very weak degree of fasciation in each generation tested so far. They are somewhat earlier than the mother variety and have small seeds due to the action of gene *sg-1* derived from mutant 489C. At Kurukshetra, the stem fasciation is not descernible. Therefore, the number of pods per plant is not increased significantly. Nevertheless, seed yield of this genotype is nearly doubled relative to that of the mother variety due to an increased number of seeds per pod and an increased seed size.

### *Flowering and Ripening*

Early flowering and ripening genotypes are of considerable importance for the dry and semi-arid regions of India. Accordingly, some early flowering mutants and recombinants of our *Pisum* collection were tested for their performance at Kurukshetra, a semi-arid region of North India.

Under West German conditions, the early ripening recombinant R 46C, which is homozygous for genes *efr* (earliness) and *bif-1* (stem bifurcation), develops blossoms at very low nodes of the plants and enters flowering time about 10 days earlier than the mother variety. At Kurukshetra, it flowers 16 days earlier. In the recombinant R 878, gene *efr* is combined with a gene for short internodes. This genotype shows in general the same flowering behaviour as R 46C, demonstrating that the gene for short internodes does not interfere with the action of gene *efr*. This holds true also for the recombinant R 879 homozygous for the genes *efr*, *bif-1* and a gene stabilizing the penetrance of *bif-1*.

A completely different behaviour was observed in mutant 2590. This is a double-mutant homozygous for two genes causing the formation of long internodes and earliness. After crossing mutant 2590 with recombinant R 46C, it became clear that the earliness of both these genotypes is conditioned by the same gene *efr* which has mutated in both embryos involved. At Kurukshetra, mutant 2590 enters flowering simultaneously with the mother variety 'Dippes Gelbe Viktoria', i.e. 16 days later than R 46C. This indicates that the gene for long internodes present in the genotype 2590 influences the action of the gene *efr* negatively. In spite of being homozygous for *efr*, the plants do not exhibit earliness. This behaviour is even more aggravated in the recombinant R 849 which is homozygous for the genes *efr*, *sg-1* (small grains) and a gene for linear stem fasciation. The plants of this genotype are late flowering, entering the flowering period 29 days later than R 46C. This negative effect can only be due to the presence of one of the above two mentioned genes derived from the mutant 489C of our collection.

In Germany, the early flowering of recombinant R 46C leads to early ripening as well. This behaviour is still more pronounced at Kurukshetra where R 46C ripens more than three weeks earlier than its mother variety. All the recombinations tested, which carry the gene *efr* for earliness, exhibit a delayed ripening in North India. They require a very long time for full ripening as is evident from the following data:

- mother variety : 43 days for seed ripening
- recombinant R 46C : 35 „ „ „ „
- recombinant R 849 : 86 „ „ „ „
- recombinant R 878 : 93 „ „ „ „
- recombinant R 879 : 87 „ „ „ „
- mutant 2590 : 99 „ „ „ „

Thus, all the above mentioned genotypes require more than double the time for ripening relative to the maternal recombinant R 46C. That means that the gene *efr* is not able to express its action with regard to early ripening under the semi-arid conditions of Kurukshetra in the gene combinations just mentioned. Even the early flowering recombinants R 878 and R 879 (12 or 18 days earlier than the mother variety) are late ripening at Kurukshetra (38 or 26 days later, respectively).

### *The Reaction of the Genotypes to the Semi-arid Climate and to Mildew Attack*

The species *Pisum sativum* is normally adapted to a mild climate with relatively low night temperatures. Under tropical conditions, the plants are affected adversely in growth and seed production. Some of the genotypes tested showed an extraordinarily high susceptibility to high temperatures. For instance, all the plants of recombinant R 674A (long internodes, stem bifurcated, low position of the first pods) died in early stages of ontogenetic development before entering flowering period. They had no infection and did not suffer from soil drought. Obviously, they died due to a specific climatic factor not yet known. As all the plants of this line showed this behaviour, the susceptibility is obviously a specific characteristic of this genotype.

Four other genotypes suffered similarly but in later developmental stages. They were able to form pods but

they died before seed ripening. Thus, it was possible to evaluate their seed production but the seeds could not be harvested. This behaviour was observed in:

- mutant 250A (long, strongly fasciated),
- recombinant R 605 (long, linearly fasciated),
- recombinant R 667 (long, linearly fasciated),
- recombinant R 848 (long, strongly fasciated).

This, however, is not a typical behaviour of fasciated *Pisum* genotypes in general but is limited to some specific forms of this group. Other ones (mutant 33B, recombinants R 849, R 853) completed their development normally.

Powdery mildew is not a serious disease of the pea plant in Middle Europe. Only very late ripening lines are affected in summers with high humidity. In India, however, powdery mildew is a serious disease causing devastating damage to peas. Therefore, it is most desirable to select genotypes resistant or tolerant to the fungus. Though this aim could not be reached, clear differences in the degree of the expression of the disease were found. The majority of genotypes tested were heavily infested by *Perenospora pisi*, showing a behaviour similar to that of the local varieties in this respect. Some of our genotypes, however, proved to be fairly tolerant to powdery mildew. This holds true for the following:

- mutant 85 (large leaves),
- recombinant R 839 (long internodes, early flowering),
- recombinant R 852 (long internodes),
- recombinant R 879 (early flowering).

These genotypes outyielded the mother variety considerably. To some extent, their high productivity could be due to their tolerance against the fungus. This behaviour will be tested in further generations.

### *Seed Production*

Most of the mutants and recominants considered in the present paper have so far been tested for their seed yield at Bonn over many generations by evaluating 200-300 plants per genotype in 4 to 6 replications per year. Thus, the values available for Bonn are very reliable. They are graphically presented in Figure 1. The main aim of growing this material at Kurukshetra was to select genotypes which exhibit a divergent reaction to the ecological conditions as compared to the behaviour of the initial line. It was found that a few of them are highly superior to the mother variety under the climatic conditions of North India and could be of interest for direct or indirect agronomic utilization. These few genotypes will be tested for their yielding properties in subsequent years. So far, data of a relatively small number of plants of one generation are available (30 to 50 plants per genotype). In spite of these limitations, certain interesting aspects become discernible from these preliminary findings.

With regard to the seed production, the material can be subdivided into three groups (Fig. 1). Group I contains those mutants and recombinants which show nearly the same behaviour at Bonn and Kurukshetra in relation to the mother variety. In this group, the Kurukshetra values lie within the range of the Bonn values. Thus, these genotypes do not differ from the mother variety in their reaction to the climatic differences existing between the two countries. But this holds true only for their seed production and differences do exist with regard to other traits of the plants.

The second group is of particular interest. It contains those genotypes which exhibit a higher relative seed productivity in North India as compared to that in Germany. This becomes clear from the fact that the Kurukshetra values are higher than the corresponding Bonn values. In some cases the differences are small; for example in:

- recombinant R 852 (long-stemmed),
- mutant 2590 (long-stemmed, early flowering),
- recombinant R 849 (fasciated, early flowering).

It could be possible that these genotypes may have to be added to group I when values for more generations are available. In other cases, however, the situation is quite clear. For instance, the tall plants of the recombinant R 667 exhibit for the character 'number of seeds per plant' mean values ranging between 116 and 180% of the control values of the mother variety at Bonn over 9 generations. At Kurukshetra, the seed production of this genotype was 276% of the control value. Even greater differences were observed for mutant 37C and recombinant

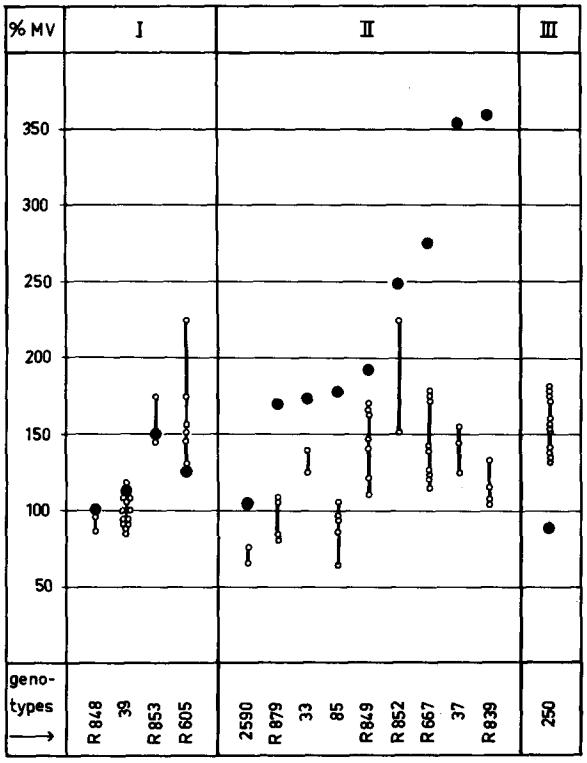


**Fig. 1.** Comparison of the seed production of 14 genotypes tested at Bonn/Germany and Kurukshetra/North India. Each dot represents the mean value for the trait 'number of seeds per plant' for one generation as related to the control value of the mother variety = 100%. Open circles = Bonn values, filled circles = Kurukshetra values, MV = mother variety

R 839. They outyield the mother variety at Bonn by 25 to 55 and 5 to 35%, respectively. At Kurukshetra, they proved to be 250 to 260% better than the initial line. The reasons for this high seed production are an increase in number of pods per plant, partly due to profuse branching, and an increased number of seeds per pod. In recombinant R 667, the seed size is also somewhat increased resulting in 200% higher total grain yield per plant (gms) than that of the mother variety. Even if these high values are not reached in subsequent generations, there is no doubt that these genotypes are definitely superior to the mother variety under the North Indian climatic conditions. They are certainly of interest for pea breeding and will be investigated further. Similar differences exist for some other genotypes also (85A, R 879); details can be seen from Figure 1.

A reverse behaviour was found for the strongly fasciated mutant 250A of our collection (Fig. 1, group III). It outyielded the initial line by 33 to 82% in the 12 generations evaluated so far at Bonn. At Kurukshetra, however, the plants of this mutant developed about 12% less seeds than the mother variety. This mutant was found to have a high degree of susceptibility to the Kurukshetra climate. Therefore, the plants died before their seeds were fully ripened. Thus, they could not be harvested and the mutant is not of any practical value in North India.

Five of the genotypes tested at Kurukshetra were also grown at Udaipur which is situated in the western parts of India (Gottschalk and Kumar, unpubl.). The seed production of these genotypes at both locations is compared in Figure 2. Recombinants R 605, R 667, R 839 and R 849 show a considerably lower seed development at Udaipur than at, Kurukshetra. This becomes especially clear in recombinants R 667 and R 605. They exhibit lower seed production at Udaipur relative to that of the mother variety. At Kurukshetra, they were physiologically much more productive and developed more seeds but the plants dried before their seeds had fully ripened, as already mentioned. More details can be seen from Figure 2.

In Table 1, some findings of the fasciated recombinants R 605 and R 667, obtained at Kurukshetra and at Udaipur, are given. Marked differences were found with regard to the duration of seed ripening. Both recombinants flower about 2 weeks later than the mother variety at both locations. At Kurukshetra, the seeds of these genotypes were seven weeks after the end of the flowering period not yet fully ripened. The definite ripening time could not be ascertained as the plants dried prematurely. In contrast, they needed one to two weeks less than the mother variety at Udaipur. With regard to the plant height relative to that of the mother variety, no significant differences occurred. The number of pods per plant, however, differed considerably between the two locations. At Kurukshetra, the recombinants R 605 and R 667 produced

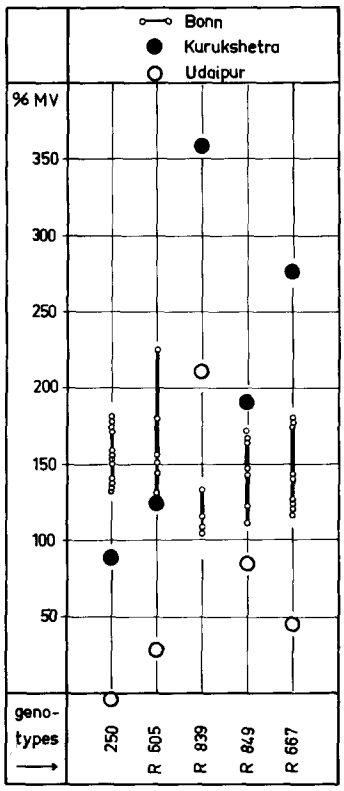


Fig. 2. Comparison of the seed production of five genotypes cultivated at Bonn/Germany, Kurukshetra/North India, and Udaipur/Western India. Arrangement as in Figure 1

24 and 92% more pods, respectively, than the initial line whereas they produced 76 and 53% less pods at Udaipur. Also with regard to seed development within the pods variations were considerable. Recombinant R 605 did not differ from the mother variety whereas it developed 16% more seeds per pod at Udaipur. The reverse situation was found for recombinant R 667 developing 44% more seeds per pod at Kurukshetra and 5% less at Udaipur.

The reaction of the fasciated mutant 250A to the ecological conditions of the three locations is of particular interest. It is one of the highest yielding mutants of our collection when grown in Middle Europe. It has already been mentioned that the plants of this genotype developed about 90% seeds of the control at Kurukshetra, but the seeds did not ripen fully since the plants of this genotype also dried up prematurely. At Udaipur, they are completely useless for pea breeding because they do not flower at all. In this respect they behave like the fasciated mutant 489C of our collection which was grown in many countries of the world. It does not flower at five climatically different locations in India as well as in Egypt and Brazil. The divergent reaction of mutant 250A at the three locations is also discernible in the shoot height. The plants are

**Table 1.** Comparison of some characters of two fasciated pea recombinants grown at two Indian locations. All the values are related to the corresponding control values of the mother variety grown at the same locations

| Trait | R 605 | | R 667 | |
|---|---|---|---|---|
| | Kurukshetra | Udaipur | Kurushetra | Udaipur |
| Days to flower | 14 days later | 13 days later | 9 days later | 16 days later |
| Days for seed ripening | 47 days more[a] | 6 days less | 51 days more[a] | 11 days less |
| Plant height | 9% longer | 20% longer | 6% longer | 19% longer |
| Number of pods per plant | 24% more | 76% less | 92% more | 53% less |
| Number of seeds per pod | 1% more | 16% more | 44% more | 5% less |
| Number of seeds per plant | 26% more | 72% less | 176% more | 56% less |

[a] Values approximate, as plants dried before all their seeds ripened fully

- at Bonn 20% taller,
- at Kurukshetra 35% taller and
- at Udaipur 23% shorter

than the initial line. At all the three locations, the stem fasciation is manifested distinctly.

The causes of such a divergent behaviour of the genotypes tested at the three locations are not yet clear because a phytotron is not available to us. Main climatic differences between the two Indian locations refer to the temperature factors Udaipur being comparatively more hotter than Kurukshetra. This could be the reason why the number of pods per plant was strongly reduced in some genotypes at Udaipur in spite of their rich flowering whereas the number of seeds per pod was not influenced negatively. The soil moisture cannot be the factor responsible for the different reactions of the genotypes because the plants were sufficiently irrigated at both the locations.

## Discussion

The penetrance of the majority of mutant genes is stable irrespective of the ecological conditions under which the respective mutants are grown. In a relatively small number of cases, distinct environmental factors influence the penetrance behaviour of the genes in such a way that they are unable to manifest their action. This holds particularly true for many chlorophyll mutants of different species, the chlorophyll production of which depends on temperature or light intensity. Not only such quantitative characters but even qualitative traits are influenced in exceptional cases by the environmental factors. The gene *bif-1* of the *Pisum* genome, for instance, causing dichotomous stem bifurcation, is unable to manifest itself under mediterranean, subtropical and tropical climatic conditions. This holds also true for the gene *dgl* causing strong leaf degeneration. This gene needs relatively low temperatures for its expression (Gottschalk 1978b, 1979).

Similar experiences were made with regard to one of our fasciated genotypes. Recombinant R 853 is homozygous for a gene causing weak degree of stem fasciation when grown in Middle Europe. The penetrance of this gene is stable, i.e. its action is discernible in every individual plant that is homozygous for this gene. In North India, however, all the plants of this genotype are non-fasciated. Thus, the climatic conditions of this region inhibit the action of this gene whereas the action of the two other genes of the *Pisum* genome causing stem fasciation is not influenced. A few years ago a fasciated pea recombinant was selected which did not show stem fasciation at Kurukshetra and Varanasi when sown during the normal sowing time. Sown four weeks later, all the plants were fasciated (Gottschalk and Kaul 1975). In this case the gene manifestation depended obviously on photoperiod.

Stem fasciation has proved to be a particularly interesting problem for gene-ecological investigations. All the fasciated recombinants tested in India are derived from the crosses between the fasciated mutant 489C and non-fasciated genotypes of our collection. The high-yielding mutant 489C is homozygous for at least three, possibly four different genes causing different types of stem fasciation and belonging to an epistatic-hypostatic series (Gottschalk 1977). Throughout India, mutant 489C does not flower and thus their favourable yielding properties cannot be utilized in tropical and subtropical countries. This holds also true for a few other fasciated mutants of our collection. Interestingly, this is not the case with regard to some fasciated recombinants. On the contrary, some of them are highly productive in North India outyielding the mother variety considerably more than in Germany, Thus, they are of great agronomic interest and are being tested further.

Earliness of pea lines is likewise of direct importance in India, not only because of dry, hot summers during which water supply is scanty but also for freeing the land from this crop earlier for subsequent cultivation. In this context, the early flowering and ripening recombinant R 46C, homozygous for gene *efr*, was found to exhibit a pronounced drought resistance thus making it superior to the mother variety and other genotypes (Gottschalk and Kumar 1972). In Germany, it is without any agronomic value because of its reduced yield. In the material studied presently, the action of gene *efr* was tested in some other gene combinations. In those cases, in which the gene expressed its action, early flowering did not lead to early ripening because the seeds of these genotypes need a very long time to ripen. In a specific combination of *efr* with a gene for long internodes, gene *efr* is completely unable to express its action. This behaviour, however, is obtained only under North Indian conditions whereas in Germany the gene *efr* is fully active in this recombinant.

With regard to the seed productivity of the genotypes tested, no definite conclusions can be drawn at this stage because values for only one generation in India are available so far while the material was tested at Bonn over many generations. However, the preliminary findings indicate that some of the genotypes are definitely superior to the mother variety. This holds true not only for the seed production but also for the increased degree of tolerance against heat and mildew attack in comparison to that of the initial line. This is a very important problem in India; however, further investigations are necessary in order to test the utility of these genotypes. The differences in the performance behaviour of distinct genotypes, simultaneously grown at Kurukshetra and Udaipur, demonstrate the importance of studying their gene-ecological reaction under different climatic conditions even within the same country. Only in this way, the specific adaptability of specific genotypes to distinct ecological niches can be discerned. These experiences can certainly be generalized. Undoubtedly, many mutants and recombinants of different crops, existing in various countries since decades and not being agronomically used, could be utilized for breeding purposes if the whole breadth of their ecological reaction would be known.

A theoretical problem of mutation genetic basic research is the delimitation of identical and allelic genes. It is the opinion of some geneticists that the same mutational event does not occur in different embryos. Even if independently arisen mutants are phenotypically identical, giving hybrids of the parental type and showing no segregation in further generations, this behaviour cannot be considered as an evidence of identity of the respective genes. It is not certain that the same locus is involved in such cases. Different alleles of the same gene could have arisen which do not cause differences that can phenotypically be discerned. The fasciated mutant 250A of our collection is a typical example for such a situation. It is phenotypically identical with mutant 489C. The $F_1$ hybrids resemble the parental mutants and no segregations were observed in $F_2$. After having grown these two mutants in North India, however, clear differences in their behaviour became evident. While mutant 489C does not flower at all, 250A flowers richly and produces a fairly good amount of seeds. Thus, the two mutants cannot be genetically identical. They contain multiple alleles for the same type of stem fasciation which mimic the presence of identical alleles.

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