Journal of Spices and Aromatic Crops
Vol. 33 (2): 144-161 (2024)
10.25081/josac.2024.v33.i2.9532

Indian Society for Spices

The bandwagons I followed as seed spices breeder

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Received 24 May 2024; Revised 01 December 2024; Accepted 03 December 2024

Abstract

Bandwagons are waves that the breeders sail. This writing is based on the articles of Simmonds (1991) and Bernardo (2016) which point to different waves created by contemporary researches which influence breeders in their work. Seed spices are important group of crops of North and Northwestern India and this article chronicles the important phases through which seed spices breeding has undergone. While conventional methods of plant breeding have yielded results in seed spices, hybrid development is still taking off the ground, mutagenesis has proved its mettle and molecular breeding techniques are yet to make inroads in seed spices breeding. The author is of the view that not necessarily every bandwagon be adopted by seed spices breeders, but due diligence should be given if a new technique holds promise in helping a breeder. The author has chronicled his four decades of experience to guide new breed of breeders adopting spices breeding.

Keywords: Bandwagon, seed spices, ideotype, hybrid, molecular plant breeding

The title of this writeup was borrowed from a publication written by Dr. N. W. Simmonds who was an acclaimed breeder and a writer. In his article Simmonds (1991), dealt with the changes that have happened in plant breeding. I am inspired to write this piece by the last sentence of the article inserted into it by the editor of TAA newsletter which I quote here-"Members may like to add their own favourite bandwagon" (Simmonds 1991).

A bandwagon is an idea, activity or cause that becomes increasingly fashionable as more and more people adopt in. In words of Dr. Simmonds-

"A bandwagon is merely the obvious response to a new idea or technique which promises well: if you can't beat 'em, join 'em. And if the bandwagon is a good one (allied to competent publicity) it becomes a gravy train; a seat on it nearly guarantees funds, grants and other

goodies such as easy (and not too roughly refereed) publication, attendance at conferences and so on".

How true the words are. We as scientists have lived and follow these new types of discoveries, myths or illusions and like any other have followed, because if one does not, obviously he misses out the action culminating in peer recognition.

Bernardo (2016) has further elaborated on the bandwagons that are/were in vogue. The major bandwagons in the chronological order are induced polyploidy, induced mutations, crop physiology, protein gap, farming systems research and biotechnology. (Simmonds, 1991) Bernardo (2016) elaborated on the biotechnology bandwagon to include transgenic varieties (which was only a possibility till the previous century), molecular plant breeding starting with molecular markers and QTL mapping, association mapping, genome wide selection and new bandwagons which details about the role of genotype and environment best explained by the equation P=G+E.

Generally bandwagon loses its stature once its usefulness is exploited and becomes a part of mainstream thinking and practice. To illustrate this point, Bernardo (2016), explains how hybrid maize by Shull (1952) gained acceptance as the standard method of exploiting heterosis and developing hybrids.

It is also essential to state that all the researches in crops basically aims to develop varieties which are stable and acceptable. Over the years a number of varieties have been developed in seed spices, generally under the umbrella of ICAR-All India Coordinated Research Project on Spices (AICRPS) (AICRPS 2024). Most of the work presented here therefore has been carried out under this broad umbrella. Our centre Sri Karn Narendra College of Agriculture (SKN College of Agriculture) has accumulated a wealth of germplasm accessions in coriander (855), cumin (376), fennel (291) and fenugreek (373) (Sharma 2023) and has developed several varieties. List of varieties that have been developed and released are listed in (Singh *et al.,* 2015, Aravind *et al.,* 2020), been developed through different bandwagons that are being described below.

Among the seed spices we have concentrated on four seed spices namely coriander, cumin, fennel and fenugreek which are categorised as major seed spices because of extensive cultivation, and significant production.

My first encounter with seed spices happened in the biannual workshop of ICAR-AICRP on spices in 1984. In those days, the workshops of the projects were conducted biannually. The spices project is a very broad one dealing with a long list of crops from perennial spices (black pepper, cardamom, cloves, cinnamon, *etc.*) to annuals (the seed spices); crops which vary in their geographical adaptation like the perennial spices which are grown only in South India to some of the seed spices like cumin growing only in Western Indian states of Gujarat and Rajasthan to such crops which show pan India presence like coriander. It is really herculean task to put

such varied goods into one basket and prepare plans. Dr. Edison along with Dr. R. K. Sharma (Jobner), (Late) Dr. T. Rama Rao (Lam), have discussed all the issues related to breeding of spices. Almost four decades later (2023) I was chairing the session on genetic resources at the XXXIV workshop of AICRP on Spices at UAS, Bangalore (Mukesh Sankar *et al.,* 2023). Ironically, the issues that we discussed are the same but with little more fineness.

Bandwagon I: Chromosomal manipulations

While in major crops like wheat, rice *etc*., people were talking about chromosomal engineering and their use in either easing the tasks or transferring the genes into cultivated spices. This has become a common buzz word, and every plant breeder was supposed to know and use these techniques. As a young researcher we jumped onto the bandwagon. We wanted to create super spices. Lucky for us that at Jobner we already had an unique plant in fenugreek which was unique in all respects, the leaves are double the size of normal fenugreek plant, the number leaves were less, seeds double the size of the normal seeds and the number of seeds per pod were less than the cultivated one and so on. It was looking like a tetraploid in all respects. However, plant was not a tetraploid but a normal diploid (Vinod 1989), hence we named it Gigas mutant (Vinod & Sastry 1998). The plant was very promising, and we started exploring using this as a genotype for creating leafy type fenugreek, although the leathery feeling of the leaves was a deterrent for transfer. Our other priorities made us to put to rest our further ventures into chromosomal manipulations. As far as I know, attempts on chromosomal manipulations have not been tried out in seed spices. We simply disembarked this bandwagon. With the advent of biotechnology, particularly the transgenics, it is however, refreshing to see a study devoted to cytogenetic analysis in coriander in recent times (Khakshour *et al.,* 2024).

Bandwagon 2: Genetic resources and their maintenance

Although this is not a bandwagon as listed by either Simmonds (1991) or Bernardo (2016), it is important to discuss and in my view this is one such bandwagon which is ever alive and will continue to be so in future. Genetic resources are the bread and butter for any crop improvement programme. All the programmes start with this and become successful depending upon the genetic variation that is present in the germplasm. I have included a detailed account on the genetic resources in seed spices in Sastry (2024). Maintenance of genetic resources in seed spices is tricky. Among the major seed spices other than fenugreek, all most all the spices are cross pollinated. Thus, one can't maintain lines just like that of pure lines. It is important that the genetic structure of each line should be maintained so that the genetic speciality of the line is maintained well. Individual plant can't be selfed and maintained as that will introduce inbreeding depression and loss of the population structure. Hence my peer Dr. R. K. Sharma devised mechanism of sib mating by caging entire line using muslin cloth. In umbelliferous crops, the

cross pollination happens through bees. Hence one has to be careful that bees visit the lines, and the bees do not criss-cross the lines to induce unwanted pollination. This in all the seed spices which we have been working. In order to maintain the genetic structure, we have been following staggard plantation generally following a 4-year cycle of maintenance (Sastry, 2007).

Characterization and evaluation of germplasm is also an important at SKN College of Agriculture part of our activities. While in other crops a detailed descriptor list was available, the same was not available in seed spices. The first attempt to create a descriptor list of the seed spices in India was made by All India Coordinated spices and cashew nut improvement project (Anonymous 1983). The descriptor list was very minimal and made up of evaluation data. Another good effort has been made by NRCSS, Ajmer to prepare a descriptor list for the spices crops (Malhotra & Vashishtha 2006), this is also minimal in its description and needed standardization. Both these lists are meant for all types of seed spices whether they belong to umbelliferae or otherwise. Of the 19 characters described by Anonymous (1983), 4 can be said to be characterization data. These are growth habit, grain colour at maturity, pigmentation on the stem and grain breakability or split habit. Similarly, out of the 28 characters listed by Malhotra and Vashishtha (2006), ten can be said to be characterization, data. Unfortunately most of them are not stable. The first study to properly describe the plant in terms of germplasm characterisation and evaluation started with the study in coriander by Choudhary (1987) who recognized five clear cut growth stages. These are listed below.

Stage I: Appearance of first compound lead to beginning of bolt formation.

Stage II: Beginning of bolt formation till elongation starts.

Stage III: Initiation of elongation to complete differentiation of main shoot into nodes and internodes and appearance of flowers.

Stage IV: Flowering stage with the beginning of initiation of flowering and termination with the initiation of grain formation.

Stage V: This stage occurs as the flowering period is complete and development of grains starts. It terminates as soon as grains in main umbels are turning brown.

Evaluation of germplasm has indicated that there is wide variation with regard to the duration of each of the stages. Leaf structure and pattern changes as coriander plant grow. Further, Diederichsen (1996) has shown that the leaf shape and size vary across continents and it should be possible to distinguish the origin of an accession simply by observing the shape of the leaves. But the collections at S K N College of Agriculture did not show much variation with regard to the types of shapes that were listed by Diederichsen (1996). Yet distinctions were noted (Sastry *et al.,* 2011). Accordingly we have proposed changes that can be made to the descritptor list and modify the same to make it more objective. As an offshoot of the discussions, in 2009 a

series of publications on descriptor lists of seed spices were generated and published by ICAR-NRCSS, Ajmer. It was relatively easier in coriander to generate descriptor lists as distinguishing characters and variations were noted, similar exercise proved challenging in cumin and to some extent in fennel (Divakara Sastry & Anandaraj, 2013).

Bandwagon 3: Induced mutations

Induced mutations are the ultimate promise to create variation. Variation is very valuable in seed spices. Although all the studies do point out that variation is sufficient in seed spices, crops like cumin face limitations due to narrow genetic diversity and a scarcity of morphological markers. These factors hinder characterization efforts, making induced mutagenesis a promising approach. Moreover, soon after the chromosomal manipulations, induced mutagenesis was the new bandwagon. Embarking this bandwagon is something that was exiting in mid-eighties. All available mutagens both physical and chemical were used for mutagenesis. The prominent mutagens we used were gamma rays, as it was easier to get among the physical mutagens and EMS among the chemical mutagens. Positive results were obtained in all the four seed spices we worked – coriander (Singh *et al.*, 1992), cumin (Koli *et al.*, 2000, Sastry & Sharma, 2008), fennel and fenugreek (Yadav *et al.*, 1998). As all the crops (except fenugreek) are cross pollinated, one has to be careful to observe whether a particular plant obtained is the result of mutation or recombination due to cross pollination. Our method of close intermating for maintenance of the germplasm has addressed this problem and the variation we generated was truly mutagenic in origin. Although some unique plants were observed, many of them either withered or were found unpromising. Major objective with which mutagenesis was attempted was not only to create variation for yield and yield attributes, but to get desirable resistance against wilts and blights which were the major diseases. Fortunately or unfortunately we could not address this problem positively. It will not be out of place to mention the revolution in cumin cultivation brought by GC-4. Readers are strongly advised to read Chauhan *et al.*, (2023).

Bandwagon 4: Ideotype breeding

The concept of ideotype was first proposed by Donald (1968). Since its proposal, several breeders have started developing their own ideotypes for different crops and for different situations. Ideotypes can be likened to a design of plant, just like a design that is made for a machine. Ideotype design needs inputs on different characters and their interrelationships to understand and manipulate them for specific situations. With the availability of simulation models, ideotype designing has become an easier task.

In seed spices breeding, the main objective has been to increase the seed yield, as it is the economic part of the plant. Hence, all the efforts have been put to improving the seed yield. Most of the varieties that have been released have been released with this single

objective with later addition of essential oil content.

In terms of seed spices, the situations which demand a specific ideotype are listed below (Sastry 2018)-

1. Threat of global warming and shifting seasonal pattern
2. Organic farming
3. Specialty varieties – varieties with better quality parameters including the extractable chemical constituents.
4. Urban agriculture

We started looking at these issues. For this we started to screen all the available germplasm first to look for distinctive features and their associations in such a way that a distinctive plant type may be designed. Coriander was taken as model crop to start with.

Coriander is used both as herb (for leaves) as well as for seed. The seeds as well as plant parts contain essential oil which impart the typical flavour to the coriander. The general cultivation method includes sowing of seeds by broadcasting either in raised beds or in flat beds and harvesting the leaves either by cutting at an interval of 25 to 30 days (generally two cuttings are taken) or by uprooting the plants at 25-30 days when sown for leaves and broad casting or line sowing when the crop is intended for seeds. A good account of the plant type is given by Diederichsen (1996) and Sastry *et al.,* (2011). Distinct changes were seen in plant type during the life cycle of the plant. Based on the differences in the plant shape, three types were recognized- prostrate (spreading), semi erect and erect (Sastry *et al.,* 2011). The spreading types are better suited for leaf purposes as their biomass is more and they rapidly grow. But when one is interested in seed types, the erect plant is found to be better suited. Most of the morphological traits showed high genetic diversity and are positively correlated with seed yield. Most important, there is a positive correlation of seed yield with the days to flowering and maturity (Pandey, 2013) or the correlations are very weak with high positive direct effect (Idhol *et al.,* 2011). This needed some relook. For further understanding, a detailed study of the different types of flowering characters and morphological traits as well as seed yield was studied with a view to understand the flowering behaviour and morphological traits which impact yield (Pandey, 2013). The multivariate analysis based on principal component analysis of all the genotypes indicated wide variation among the genotypes. Further analysis of the characters has indicated two distinct groups of characters those related to flowering and morphological characters. This indicates importance of the flowering duration in the seed yield. Further, when the genotypes were categorized based on the seed yield, the top yielding genotypes were in general long duration varieties, while the low yielding genotypes were generally early to flower and to mature (Sastry *et al.,* 2016). This ideotype is based on flowering initiation and flowering duration as a means of developing varieties suitable for different agroclimatic zones (Sastry, 2017). With this in mind further breeding program mmes were started with two-way approach, genotypes better suited for high seed yield

with shorter duration and genotypes that are better suited for high leaf yield.

Rather than generating genotypes which are better leaf yielders to cater to urban markets, we wanted to generate dual purpose genotypes. Our aim was to develop genotypes which generate income from leaf yield (with at least two cuts) and with desirable seed yield in the end. Naturally such genotypes will perform better only in intensive management conditions. Initial studies have shown that there is a negative correlation with number of leaf cuts and final seed yield. Thus, the genotypes with semi spreading types were suited for this purpose as the leaf yield from these genotypes was better than the erect types while with the spreading types, the final seed yield was not promising. Refinements in this direction were going on and hopes are still going on. More studies on physiology of the coriander plant are needed.

We could not make much progress in such studies in other spices, namely fennel, fenugreek and cumin.

In cumin most of the collections we had in our germplasm are erect types with less variation. No significant headway was achieved with the mutagenesis either. Gujarat Cumin 4 (GC-4) is very distinctive which is bushy and is dark green in comparison to the ruling varieties of cumin of the day (Chauhan *et al.,* 2023).

Fennel is a long duration crop among all the major spices. Its plant is tall almost reaching 150 centimeters or more. The umbels are more indeterminate. Further, fennel is direct seeded as well as transplanted. The transplanted cultivation is more common in Gujarat. Our ideotype therefore had been a plant with height around 100-120 cm with higher umbels and umbellets which directly translated into higher seed yield. Generally transplanted fennel takes longer duration than direct seeded type. At ICAR-NRCSS, Ajmer dwarf types have been generated using mutagenesis (National Research Centre on Seed Spices, 2013).

Bandwagon 5: Hybridization and hybrid development

We were attracted to this bandwagon because, exploitation of heterosis is a common practice in most of the horticultural crops and we also wanted to put hybrids in the hand of the farmer. Moreover, other than fenugreek, all the other crops being cross pollinated in nature, presented us an opportunity to exploit the heterosis. The problem for this venture has been the structure of the flower and pollination control. The flowers of these crops are very delicate and difficult to handle for emasculation and pollination. Selfing is easy but controlled crossing is difficult. Fennel proved to be a success for hybridization as well for of developing hybrids. This crop also presented us an opportunity to study its genetics. This all started with an easy method of emasculation as well as crossing (Singh *et al.,* 2000). With this tool in hand, we planned and conducted several studies for understanding the genetics. Most of these studies were based on varietal diallel analysis as proposed by Gardner & Eberhart (1966). All the studies (Ramanujam & Tiwari, 1970; Dashora *et al.,* 2003; 2009;

Rajput & Jakhar, 2013) have indicated that yield and yield related traits in fennel were under the control of both additive and non-additive gene action with ample heterosis. To exploit this heterosis by developing hybrids, inbred line development was needed. We started that and initially two varieties were selected (RF 125 and RF 205). The inbred development programme started with selfing of randomly selected plants. This continued for almost seven generations and by the end of this programme the inbred lines showed stability. Although some of the lines showed variation for the plant type. We suspected random pollination as the cause, but the very nature of crop was such that even in inbred lines some amount of variation was observed. We had more than 180 inbreds which were found to be stable. An initial evaluation of the inbreds was carried out (Jeeterwal *et al.,* 2015) which showed ample variation for morphological traits which affect seed yield in fennel inbreds. At present the evaluation traits for estimation of combining ability and selection of promising crosses is going on (Dr. Gothwal, Personal communication). Once this step passes through, hybrid varieties can be easily developed which will be a landmark in the seed spices improvement programme. Fortunately, we now have doubled haploidy technique as means of generating inbreds in fennel as well as in dill (Ferrie, 2021).

Quality of inbreds depends on their genetic worth which in turn depends on the population from which they originated. Hence, simultaneously we were also working on population improvement to find out the best method to get high genetic advance (Singh & Sastry 2003; 2004; 2005).

We were not so lucky in finding easy solutions for emasculation; therefore, we could not make much progress in hybridization and hybrid development in coriander, cumin and fenugreek, primarily because of the problem of emasculation. Not that means were not tried, e.g. use of gametocides in coriander as reported by Kalidasu *et al.,* (2009).

Bandwagon 6: Protein gap rechristened by me as "essential oil surge".

Dr. Simmonds mentions protein gap as one such area that attracted several breeders to it to either improve the protein quantity or quality. We were rarely attracted to this area as spices are never grown for their protein quantity or quality. Both are of less importance though essential oil is an important flavouring component in spices. Our aim was to improve the essential oil quantity. This was therefore incorporated as an important aspect in the varietal release parameters (Aravind *et al.,* 2020). We have given importance to this aspect, sometimes directly and sometimes indirectly. Directly when we started breeding for lines which have high oil content. However, screening of the germplasm available with us has shown very low variability and therefore selection solely for essential oil content made less headway. Instead, we laid importance to essential oil yield per unit area. Our studies have shown that there is a positive correlation between essential oil content and seed yield in the varieties developed at Jobner. We also observed that the exotic

genotypes in general had higher oil content than the indigenous ones (Sastry *et al.,* 2011). Isolated reports have fractionated essential oil of seed spices and found varying number of components which impart flavour (Parthasarathy & John Zachariah, 2008; Nurzynska-Wierdak, 2013; Srinivasan, 2018; Dar *et al.,* 2019; Saxena *et al.,* 2020). If we could pinpoint few essential fractions of essential oil which impart the quality for that spice, then specific breeding programmes aimed at improving that component can be planned. These could be turned as speciality varieties. Coupled with advances in molecular breeding techniques it should not be distant date when we can put such speciality varieties in the hands of the consumer.

Bandwagon 7: Biotechnology and molecular breeding

This is one bandwagon, I do not know why, by design or default we the seed spice breeders have not jumped yet, not that the wagon is not ready or was not beaconing, but perhaps, the cost and returns may be the consideration for adopting these techniques. One reason being that the application of the molecular techniques is still in experimental stages even in crops which attract large private funding. As Dr. Simmonds writes, there is more glamour attached to it than it may have deserved. In major field crops we do see many achievements from the area (Khan *et al.,* 2024). In the 90s there was lot of hype and biotechnology which included molecular techniques in plant breeding was projected as panacea for several of the issues that breeders face. As member of the editorial board of Indian Journal of Genetics and Plant Breeding, we even decided that more space will be given to works based on molecular plant breeding. Seed spices researchers were however slow to adopt these techniques for the reasons as cited above. Dedicated laboratories which dealt with these techniques were limited. ICAR-IISR, Khozhikode was the first to establish dedicated laboratories for molecular breeding, similar to several of commodity institutes under ICAR. In a first of its kind of study, using flow cytometric studies, Tomar *et al.,* (2022) have shown that the total 2C content is higher in fenugreek than the seed spices of Apiaceae (coriander, cumin and fennel), all the species are diploid and have originated in mediterranean region.

One can see successive molecular bandwagons which have influenced plant breeding. We can also see that several of the techniques of biotechnology which were supposed to be main stay have become subsidiary tools to these molecular bandwagons. The important bandwagon that had made the most impact has been development of transgenic varieties. Flavr Savr of tomato starting the trend. This was followed by widespread use of Bt gene in cotton, maize and then on to several of crops. This has also led to debate on several aspects which is still continuing. Nevertheless, we can't deny that transgenic varieties have made their foothold and going to stay for some more time.

Further, extending the observations of Simmonds and Bernardo (2016) have classified this biotechnology era into several of the bandwagons that have come, in chronological order we see molecular

markers and QTL mapping, association mapping, genome wide selection and bandwagons related to P=G+E.

In the recent times we have seen the whole genome sequencing has been done in coriander, fennel and fenugreek.

Some of the salient works in this area are summarised below-

A review on the available information on the use of biotechnological interventions in coriander is compiled by Varsha Kumari *et al.,* (2024). The possible areas include genome editing using CRISPR/Cas9 (Arora & Narula 2017), A complete sequence of coriander (Song *et al.,* 2020b; a) and fennel (Scariolo *et al.,* 2022) are already available. In a study of ARF (auxin response factors) which regulate plant growth and development, Pei *et al.,* (2021) have shown that prologous gene number was higher in comparison to close relatives like carrots and celery. With the knowledge of this group of family, efforts to modify the flowering behaviour in coriander leading to development of higher productivity varieties is anticipated.

Diversity among the coriander germplasm was studied using molecular markers (Sharma *et al.,* 2019; Palanikumar *et al.,* 2024). Diverse molecular markers have been studied and the studies have shown existence of ample diversity among coriander lines (Choudhary *et al.,* 2019; Palanikumar *et al.,* 2024). Genomic, transcriptomic and metabolic databases of coriander are maintained by North China University of Science and Technology, Tangshan, Hebei, China (http://cgdb.bio2db.com/). The comparison of the genome with coriander and carrot based on seven transcription factor (TF) families reveal their relatedness (Song *et al.,* 2020a).

We have been maintaining that the variation in cumin is very limited. Even assessment of variability using molecular markers have also shown the same (Mousa *et al.,* 2023). Some variation in the content of DNA is noted among the varieties of cumin (Hasan *et al.,* 2016), which may indicate that morphological variation is possible in cumin. Using 10 SRAP markers, Bhatt *et al.,* (2017) have shown a Jaccard similarity coefficient to be only 0.59 among 16 genotypes which indicated low to moderate variability among the genotypes of cumin. Although out of the 4 genotypes studied by them, RZ 19 and RZ 209 were very diverse (it will be noteworthy to mention that these two were the ruling varieties till GC-4 was released in Rajasthan) than RZ 241 and RZ 345. Similar conclusions can also be seen in the report of Choudhary *et al.,* (2015). Studies using ISSR markers in Egyptian land races have shown that the geographical diversity had higher influence on the genetic diversity (Ahmed *et al.,* 2024). Going a step further, Mortazavian & Bidgoli (2024) used the ISSR markers successfully to select promising progenies using half-sib progeny method to develop drought tolerant lines in cumin.

The diversity reported among the collections of fennel is also low. The same is also reported using molecular markers by Maruzy *et al.,* (2024). As expected, geographical diversity influences genetic

diversity and the same is proved even using ISSR and SCoT markers (Choudhary *et al.,* 2018; Ramadan *et al.,* 2019). Akbari *et al.,* (2024) have demonstrated the usefulness of ISSR markers' usefulness in discerning variability in fennel. Salami *et al.,* (2017) have distinguished two separate groups – selfed and outcrossed populations which could be distinguished using the molecular markers.

From the molecular biology point of view, studies on fenugreek, is more in comparison to other three seed spices. In a study on diversity using 24 inter-primer binding site (iPBS) markers in fenugreek genotypes obtained from 18 countries by Haliloğlu *et al.,* (2024), revealed differences among the groups of genotypes with respect to these markers. High density SNP based mapping has shown the closeness of fenugreek to clover (Abd El-Wahab *et al.,* 2020). Transcriptome data with regard to important secondary metabolites is known (Naika *et al.,* 2022). Similarly, the diosgenin biosynthesis genes have been identified (Ciura *et al.,* 2017).

For breeding speciality varieties, it is essential we know the pathway of the quality compounds present in the spices. In fennel, the flavour which is ascribed to the presence of t-anethole has long been recognised as the important compound. Palumbo *et al.,* (2018) have published the possible gene transcripts of t-anethole, therefore using the molecular breeding techniques we should now be able to breed speciality varieties, although it requires further confirmatory studies. For large scale seed production of hybrids, easy methods of emasculation are needed. But it would be efficient to use CGMS system. Pank *et al.,* (2007) and Scariolo *et al.,* (2022) have reported the presence of male sterility whether it is usable or not has to be studied in our environment. Palumbo *et al.,* (2020) have studied the nature of the male sterility in fennel and reported that two atp6 like sequences determine the male sterility. This should be explored for commercial exploitation to make the hybrids in fennel economically viable.

Towards the end, it is worthwhile to mention studies on mega environment analysis for the genotype environment interaction and subsequent selections for the specific environments. The importance of G X E interactions in crop improvement programme, are obvious. We have initiated an evaluation of all available germplasm across the country for seed spices, with the aim of characterizing environments and identifying suitable genotypes for specific environments. This was a mammoth study undertaken as part of AICRP activity involving all the centres, the studies have given valuable insight into the G X E interactions (Giridhar *et al.,* 2023).

Conclusion

Bandwagons have their own life cycle. Depending upon new innovations that constantly happens in sciences, new thinking/ technology is adopted, and the old thinking loses followers. The same is true in seed spices improvement. There is a possibility that I may have missed important innovations or ideas that may have helped me (us) not by design anyway.

Acknowledgements

No one can work in isolation and work like breeding varieties is never a solitary venture. I would like to thank my seniors Dr R. K. Sharma, pioneer seed spices breeder in India and my mentor has actually initiated me into spices breeding. I am fortunate that I had colleagues like Drs Dhirendra Singh, S P S Rajput with whom I worked and learned a lot. I cannot forget my fellow scientists from other disciplines starting from (Late) Dr. H.R. Agrawal, (Late) Dr. M. P. Jain, Drs G.R. Chaudhary, N.L. Jat, K.S. Shekhawat, A.C. Shivran. Persons like Dr. M. Anandaraj, Dr. V.A. Parthasarathy, Dr K. Nirmal Babu have been giving the needed push whenever it was needed for our breeding efforts. I have been associated with the National Research Centre on Seed Spices located at Tabiji, Ajmer right from its site selection, naturally it is dear to me and all the Directors and scientists since its inception have been very cooperative and have given a free hand to use their facilities.

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