SEMINAR REPORT

SEED VIVIPARY- CAUSES AND IMPACTS

By

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Department of Seed Science and Technology

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CERTIFICATE

This is to certify that the seminar report entitled “Seed vivipary- causes and impacts” has been solely prepared by Milu Herbert (2018-11-155), under my guidance and has not been copied from seminar reports of any seniors, juniors or fellow students.

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DECLARATION

I, Milu Herbert (2018-11-155) declare that the seminar entitled “Seed vivipary- causes and impacts” has been prepared by me, after going through various references cited at the end and has not been copied from any of my fellow students.

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12-12-2019 (2018-11-155)

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1. Introduction

In plants, the mostthe most common method of reproduction is through seeds. Seeds are central to crop production, human nutrition, and food security. Seeds in fruits do not generally germinate while remaining in the fruits, even at full maturity. In some cultivars, however, seed sprouting during fruit development has beenis observed. This discrepancy is more in the context of climate change and can cause unexpected and serious problem in commercial seed production.

'Vivipary' in plants is defined as a unique and rare reproductive strategy where seedlings are precociously produced while still on the maternal parent. Several investigators have observed this phenomenon in crops such as tomato, bell pepper, *etc* cucurbits *etc*., where theyand have used different terms such as precocious germination, pre harvest sprouting, viviparous germination and ; viviparous sprouting to designate this physiological disorder. They used terms such as precocious germination, pre harvest sprouting, viviparous germination, viviparous sprouting etc.

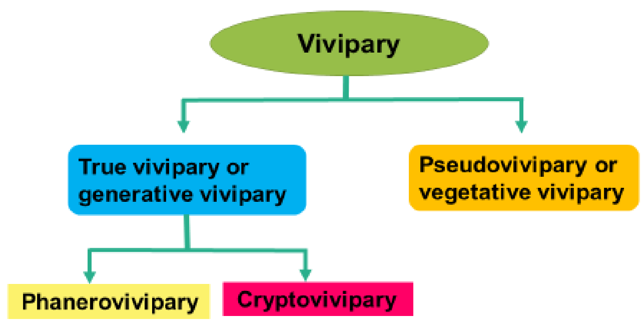
Several evolutionary and ecological theories have been proposed to explain the prevalence and implications of this reproductive mechanism in plants. It was regarded as a primitive character in angiosperms. It is suggested that vivipary was the rule under uniform climatic conditions of early geological periods, the mangrove swamps alone illustrated the climatic conditions once prevailing. This interpretation was is disputed by the argument that vivipary is a derived condition in special habitats, not a lost general habitat. Phylogenetic evidence suggests that vivipary is not always relict characteristics of ancient taxa; rather, these traits have evolved repeatedly in descendants of desiccation-tolerant taxa (Elmqvist and Cox, 1996). When we think of vivipary in plants, the image that flashes in our mind is that of mangroves.

2. Vivipary as a reproductive strategy- Mangroves

Vivipary is noticed naturally in some species genus of mangrove belonging to the four generasuch as (*Bruguiera, Ceriops, Kandelia and Rhizophora*), which constitute the tribe Rhizophoreae of Rhizophoraceae., I in which it is considered as an aid to for adaptation in to wet ecosystem where germinated seeds after falling in mud establish itself and grow as a plant.

Here the seedling develops without dormancy, largely by elongation of the hypocotyl to produce a cigar-shaped seedling, which remains conspicuously pendulous on the parent tree for several months. The structure is eventually fully abscised either with (*Bruguiera*, *Ceriops*, *Kandelia*) or without the fruit (*Rhizophora*).The seedlings drop from the plant into the salty water below. From there they have the potential to float long or short distances before taking root. They may land in the soil upright, but often, as the tide recedes, they find themselves lying horizontally on the soil. Luckily, they have the remarkable ability to take root and quickly stand themselves up. Doing this allows young plants to keep their "heads" above water as the tides return. It also helps protect the shoot tips from herbivory.

3. Classification of seed vivipary



Two main types of vivipary have been described in flowering plants: true vivipary and pseudovivipary, which are equally distributed (50/50) among plant families (Elmqvist and Cox 1996). In true vivipary, sexual embryo is able to germinate on maternal plant. The best-known cases of true vivipary in angiosperms are documented in mangroves of the Rhizophoraceae and Avicenniaceae (*Avicennia* L.) (Cota sanchez, 2004). In phanerovivipary (Greek *Phanero*, visible) ,), the embryo penetrates through the fruit pericarp and grows to a considerable size before dispersal such as in mangroves of the genus *Rhizophora.* Cryptovivipary (Greek *kryptos*, hidden) refers to the condition whereby the embryo significantly develops but do not penetrate the pericarp before dispersal Eg. Melons. Pseudovivipary is the transformation of some flowers or their parts or all flowers in an inflorescence into vegetative shoots that often serve as organs of vegetative propagation. It does not involve seeds and is, instead, a form of asexual reproduction. This phenomenon is widespread in monocots, particularly in the Poaceae (Elmqvist and Cox, 1996), where numerous examples have been reported.

Plate 1. Pseudovivipary in *Poa bulbosa*

Plate 2. Phanerovivipary in Chow chow

Plate 3. Cryptovivipary in Tomato

4. Impacts of seed vivipary

- Inferior seed quality
- Reduction in seed yield
- Economic loss
- Challenge in maintaining food supply
- Adverse effect on species diversity in seed bank repositories

4.1. Inferior seed quality

The emphasis on quality seed production has become more relevant in the present scenario since the contribution of quality seed alone to the total seed production accounts for 15- 20%. The reserve mobilization associated with viviparous sprouting degraded the reserve materials such as starch and proteins in seeds, creating favourable environment for infection by saprophytic fungi. This can lead to loss of seed viability and reduction in seed longevity. Athulya (2019) reported that the treatment with highest vivipary per cent gave lowest value for seed quality parameters such as germination per cent and vigour index ~~1~~ I in oriental pickling melon.

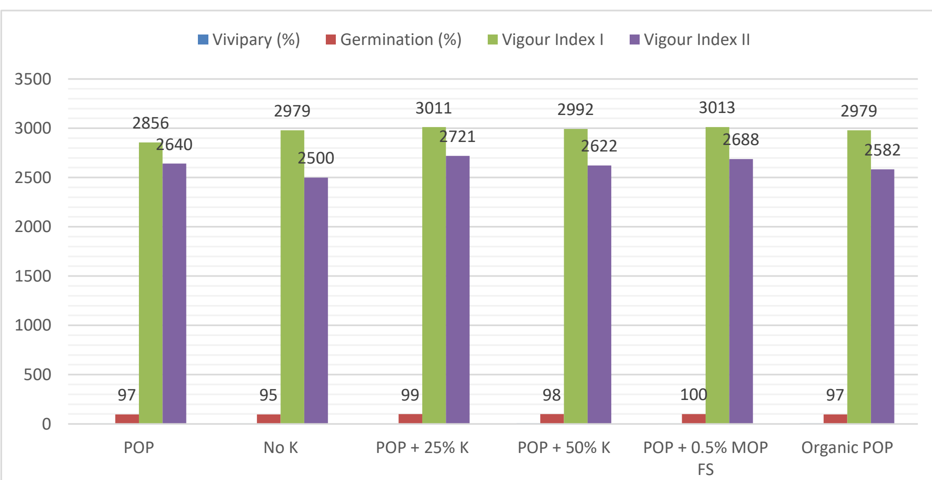


Fig. 1. Effect of vivipary on seed quality in oriental pickling melon

4.2. Reduction in seed yield

N'Gaza *et al*. (2019) reported that high rate of unfilled seeds and sprouted seeds were obtained in viviparous genotypes. These were removed from the harvest resulting in reduction in seed yield. This makes viviparous genotypes less productive than viviparous ones.

Yield parameters	**Viviparous accessions**		**Non-viviparous accessions**	
	NI128	NI153	NI063	NI189
No. of seeds per fruit	112.00 ± 33.00	112.00 ± 37.00	220.00 ± 33.00	274.00 ± 47.00
100 seed weight (g)	13.48 ± 2.25	11.54 ± 2.17	17.25 ± 3.80	20.92 ± 4.90
Viviparous seed (%)	35.88 ± 22.53	46.09 ± 21.87	0.00 ± 0.00	0.00 ± 0.00
Seed yield per plant (Kg)	0.054 ± 0.030	0.042 ± 0.025	0.218 ± 0.094	0.362 ± 0.016

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Table 1. Yield parameters of viviparous and non- viviparous accessions of bottle gourd

4.3. Economic loss

Vivipary is a nuisance in seed production as the sprouted seedlings cannot be sold as seeds thereby reducing the income. The role of precocious germination as a link to economic loss in tomato was studied by Cota ~~sanchez~~ Sanchez in 2017. He tried to raise crop from viviparous seedlings obtained from two viviparous fruits of a mutant tomato plant. He adopted two treatments- 1. Viviparous fruit left intact on the pot soil 2. Viviparous seedlings transplanted (18 seedlings). Out of the 18 seedlings transplanted, only three survived until maturity, that is, 16.7% survival and

83.3% mortality rate. Thirteen mature and fully ripened fruits were collected from the three surviving plants (five, five, and three fruits, respectively) to be screened for vivipary. After harvesting, the fruits were kept at 4 ^{0}C for 2 weeks and then dissected for inspection of vivipary. In the absence of vivipary, the seed number was estimated per fruit and per plant. All the fruits showed an estimated 71% of normal versus 29% abnormal seeds, roughly representing the loss of approximately 30% of normal (viable) seeds.

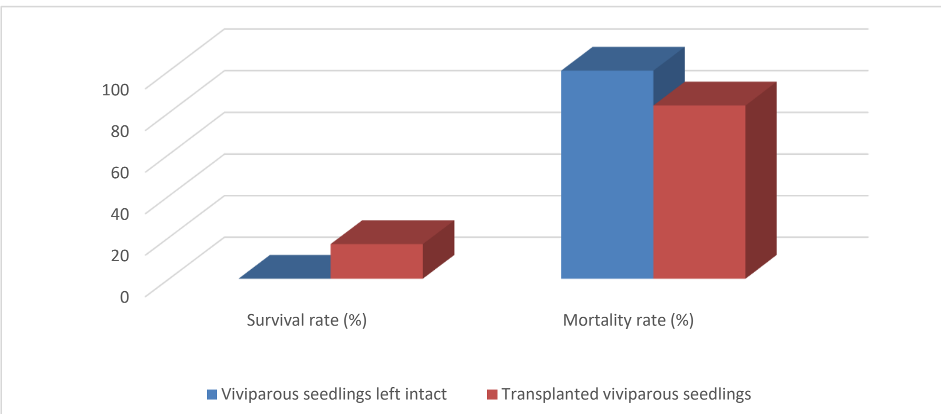

Fig. 2. Survival and mortality per cent of viviparous seedlings

Plant	Total no. of seeds (Mean)	No. of normal seeds (Mean)	No. of abnormal seeds (Mean)
1 (5 fruits)	78	54	24
2 (5 fruits)	77	54	23
3 (3 fruits)	75	57	18
Total average	77	55	22

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Table 2. Quantified data of the seeds harvested from the survived tomato plants

4.3.1. Estimated economic loss due to vivipary in Oriental Pickling melon

- Market price of OP melon seeds is Rs. 2000/ Kg
- Average seed yield of OP melon is 300 Kg/ha which gives an income of Rs. 6,00,000
- Vivipary reported in OP melon variety Mudicode is 5.36% which indicates an yield loss of 16.08 Kg/ha
- Therefore, the actual seed yield becomes 284 Kg/ ha which indicates an income of Rs. 5,67,840
- Hence, the estimated economic loss is Rs. 32,160

4.4. Challenge in maintaining food supply

Inferior seed quality with limited yields and supplies are the issues linked to seed vivipary in commercial crops. They act as sources of potential disaster in the production of major food staples. Seed dormancy is a requirement for successful agriculture because seeds harvested in previous seasons are normally stored until the next seeding cycle. Seed vivipary is linked to desiccation intolerance in seeds (recalcitrance). Consequently, seeds generally lose viability upon drying. It creates serious problem in commercial seed production by challenging traditional methods of seed storage that are not effective for viviparous seeds and hence adversely affects food supply.

4.5. Adverse effect on species diversity in seed bank repositories

'Seed banks' are seed storage facilities used as reserves to protect and restore species in case their habitats are threatened. Seed banks are also used for some traditional food crops that have become rare with conventional agriculture. Seed banks work well for orthodox species, whose seeds can store for many years and remain viable. ~~Because~~ Due to this~~of this distinction~~, many viviparous species cannot be "banked" in conventional seed banks. Instead, nurseries and seedling propagation efforts are made to conserve and restore the species.

5. Causes and control measures of seed vivipary

5.1. Physiological causes

5.1.1. Seed dormancy

Dormancy is defined as the failure of an intact, viable seed to germinate under favourable conditions. Different crop varieties have various period of dormancy. The varieties having shorter period of dormancy would easily germinate before harvest under continuous raining conditions after seed maturation. Different dormant levels could be determined by varied seed endogenous inhibitors, which usually affect seed dormancy by complicatedly interacting with each other. The dormancy was also partially caused by high level of phenolic compounds in seeds through inhibiting the cell division.

5.1.2. Endogenous hormone levels

Plant hormones, mainly abscisic acid (ABA) and gibberellin (GA), are the major endogenous factors that act antagonistically in the control of seed dormancy and germination; ABA positively regulates the induction and maintenance of dormancy, while GA enhances germination. It is speculated that these GAs induce a developmental program that leads to vivipary in the absence of normal amounts of ABA and that a reduction of GAs re-establishes an ABA/GA ratio appropriate for suppression of germination and induction of maturation.

Ochi *et a*l. (2013) studied the effect of abscisic acid treatment (A10mL solution of ABA was sprayed by hand sprayer on each fruit at 25 DAP) on viviparous sprouting of melon seeds. They found that increase in the ABA treatment concentration markedly increased the ABA content in the seeds and reduced the percent of viviparous sprouting.

Line	Abscisic acid treatment (mg L^{-1})	Percentage of viviparous sprouting (%) at 50 DAP	Abscisic acid content in juice samples around the placenta (ng g^{-1} FW)	Abscisic acid content in seeds (ng g^{-1} FW)
S·VS	0	3.67	44	22.7
S·VS	100	0.95	109	27.2
S·VS	300	0.79	252	37.0

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DAP- Days After Pollination FW- Fresh Weight

Table 3. Effect of abscisic acid treatment on viviparous sprouting of melon seeds

5.1.3. Seed coat characteristics

The seed coat exerts its germination-restrictive action by its mechanical resistance to radicle protrusion or being impermeable to water and/or oxygen. Seed coat is the first protecting wall which could prevent water absorbed into seed to increase the vivipary tolerance. The external water especially the rains once imbibed into the epidermal cells of seed, the α-amylase will be activated in the aleuronic layer and then the seeds will be germinated. Once the epidermal cells of the seed coat arranged very loosely, the varieties will be very susceptible to vivipary.

5.1.4. Fruit osmotic potential

Welbaum (1990) reported that precocious germination occurs more frequently in Armenian cucumber, because these fruit accumulate less sugar and, therefore, have a higher (less negative) fruit osmotic potential.

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5.2. Environmental causes

5.2.1. Climatic factors:

- Temperature
- Relative humidity
- Sunshine hours

Nagendra *et al.* (2017) studied ~~about~~ the effect of time of planting on seed vivipary in oriental pickling melon and found that vivipary per cent in OP melon differed significantly with different planting dates(August to February). ~~The highest value of vivipary was recorded in~~ December ~~planting~~ planted crop recorded ~~with~~ 6.25 per cent viviparous seeds which was the highest among all plantings . This may be due to high temperature, high sunshine hours and no rainfall during the flowering and fruiting stages of ~~early sown~~the crop.

5.2.2. Nutrient concentrations

- Excess nitrate nitrogen (Yamaguchi *et al*., 1967)
- Depleted potassium (Marrush *et al*., 1998)
- Depleted molybdenum (Tanner, 1978)

A high nitrate nitrogen level or lower potassium fertilization might lead to a decrease in the ABA content in fruit juice samples around the placenta, resulting in the increased occurrence of viviparous sprouting.

Ochi *et a*l. (2013) studied about the effect of high potassium fertilization level on viviparous sprouting in melon varieties S. VS. and S. VS. KY and found that high potassium ~~fertilizatio~~application~~n~~ markedly decreased the occurrence of viviparous sprouting, probably due to the increase of the endogenous ABA content in seeds.

Molybdenum (Mo) has been reported to enhance seed dormancy. Tanner (1978) discovered Mo involvement in reducing pre-harvest sprouting in maize (*Zea mays* L.). Tejakhod *et al*. (2018) studied about the effect of foliar application of ~~Molybdenum~~ molybdenum on pre harvest sprouting in Japonica rice cv. Gleva under subsequent submergence in water for four days from 30 DAA with deionized water as spray control, applied at 200 Lha-1 at flag leaf appearance. Increase pre-harvest sprouting caused by submergence, particularly from 30 DAA mitigated in part by application of Mo before anthesis, with application at 100 mg Mo L^{-1} an effective dose to gain agronomic benefit.

5.3. Genetic causes

5.3.1. Inherent variability

N'Gaza *et al*. (2019) studied about vivipary prevalence in 185 accessions of bottle gourd (*Lagenaria siceraria)* and reported that vivipary level varied among the accessions of the crop.

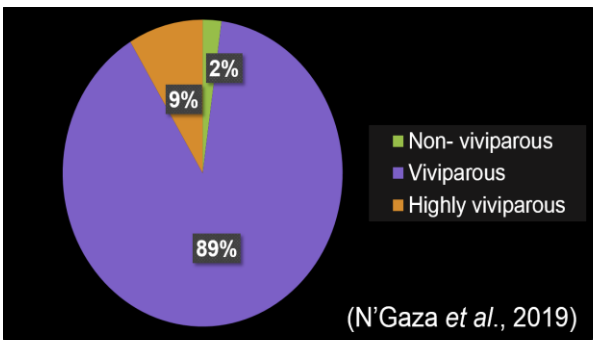

Fig. 3. Vivipary prevalence in 185 accessions of bottle gourd (*Lagenaria siceraria)*

5.3.2. Genetic mutation

Some mutant genotypes produce seeds that germinate prematurely on the parent plant. A number of mutants with reduced capacity to synthesize ABA have been described. These viviparous non dormant phenotypes reflect altered production of phytohormones or signal transduction pathways, reduced sensitivity to dormancy- inducing phytohormones and modified embryonic and adult water relations. They have reduced protein accumulation and lack of dormancy as they are impaired in different parts in the ABA biosynthesis pathway. Eg. Maize *vp14* impaired in the part of cleavage of epoxy-carotenoids to xanthoxin in the ABA biosynthesis pathway.

ABA has a major function in maintaining the water balance of plants, since it induces the closure of the stomata during water shortage. ABA prevents germination before the seeds are mature (vivipary). ABA deficient tomato mutants have wilting leaves and fruits, due to the disturbance of the water balance. In these wilting mutants, the immature seeds germinate within the tomato fruits while they are still attached to the mother plant.

Some mutant genotypes produce seeds that germinate prematurely on the parent plant. A number of mutants with reduced capacity to synthesize ABA have been described. These viviparous non dormant phenotypes reflect altered production of phytohormones or signal transduction pathways, reduced sensitivity to dormancy- inducing phytohormones and modified embryonic and adult water relations. Seeds of ABA-deficient mutants exhibit reduced protein accumulation and lack of dormancy, which leads to viviparous germination. Mutants of tomato, wheat, corn, and *Arabidopsis* exhibit viviparous phenotypes that reflect altered production of phytohormones, reduced sensitivity to dormancy-inducing phytohormones, and modified embryonic and adult water relations.

Conventionally we can go for crossing between vivipary resistant and susceptible varieties followed by selection. Genetic researches have revealed morphological markers associated with vivipary resistance. An example has been described by Gao *et al*. in wheat. They correlated the seed coat colour with vivipary and found that the white- susceptible and red-resistant. We can utilize this morphological marker to help select vivipary resistance.

6. Summary

Seed vivipary is a reproductive strategy where seedlings are precociously produced while still on the maternal parent. Impacts of seed vivipary are inferior seed quality, reduction in seed yield, economic losses and adverse effects on species diversity in seed bank repository. Vivipary is influenced by environmental, physiological and genetic factors. Environmental factors are climatic factors and nutrient concentrations. Temperature, relative humidity and sunshine hours are the climatic factors influencing vivipary in plants. Nutritional conditions such as high nitrate nitrogen or low potassium or molybdenum are reported to increase the occurrence of viviparous sprouting. The physiological factors are seed dormancy, endogenous hormone levels and seed coat characteristics. Variations in the prevalence of vivipary among different accessions of the same

crop has been reported. Some mutant genotypes in crops such as tomato, maize, rice and a few others produce seeds that germinate prematurely on the parent plant. They are known as viviparous or pre- harvest sprouting mutants with reduced capacity to synthesize abscisic acid. The control measures include chemical induction of seed dormancy through exogenous application of abscisic acid, nutrient foliar spray applications (potassium and molybdenum) and crop improvement techniques like conventional breeding and hormone engineering.

7. Conclusion

High incidence of vivipary in staple food crops is of paramount importance as it can undermine current and future productive yields and economic return for stakeholders. This trait is, therefore, detrimental in commercial crops because it causes yield and viability losses and inferior nutritional and palatable quality of fruits.

8. Discussion

1. Why mortality rate is higher in viviparous seedlings?

Ans. Sudden exposure to unfavourable external conditions and/or physical damage during the process of separation from the other seedlings make viviparous seedlings vulnerable.

2. What is the criteria for classification of accessions of bottle gourd into different classes of vivipary?

Ans. Accessions with less than 5 per cent vivipary are classified as non-viviparous, while those with 5- 95 per cent vivipary and more than 95 per cent vivipary are grouped into viviparous and highly- viviparous accessions.

3. Why fruit crops like jackfruit was not mentioned in the presentation?

Ans. In fruit crops, the most common method of propagation is vegetative propagation which does not involve seeds.

4. What is vigour index ~~1~~I?

Ans. Vigour index ~~1~~ I is calculated by multiplying germination per cent with seedling length (cm).

5. How hormone engineering alters the expression of NCED gene?

Ans.With the use of an ABA-responsive promoter to drive NCED, NCED expression can be altered by the creation of a positive feed- back loop.

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Time : 10: 45 am

Seed vivipary - Causes and impacts

Abstract

Vivipary in plants is a unique and rare reproductive strategy wherein seedlings are precociously produced while still on the maternal parent. True vivipary and pseudo-vivipary are the two types of vivipary known to exist in plants. This phenomenon is observed in mangroves, where it is an adaptation to the wetland ecosystem. However, its occurrence in cultivated crops such as tomato, bell pepper, melons, rice, maize and others is undesirable.

Vivipary leads to inferior seed quality, reduction in seed yield and is a challenge in maintaining seed storage and supply. It results in considerable economic loss, reducing the income of the seed producers. It also affects seed storage in seed bank repositories, as viviparous species cannot be ‘banked’ in seed banks.

N'Gaza *et al*. (2019) realized low seed yield in viviparous accessions of bottle gourd owing to high number of low quality and unfilled seeds. Vivipary can also negatively influence seed yield by affecting plant growth and development. It has been shown in tomato that vivipary significantly affects seedling establishment, which can indirectly influence the seed yield by reducing one-third of the normal seed yield (Cota-Sanchez, 2017).

Vivipary is the result of various physiological, environmental and genetic factors (Fransworth, 2000). Period and level of dormancy, balance between the phytohormones - abscisic acid (ABA) and gibberellic acid (GA), mechanical resistance of seed coat and fruit osmotic

potential may induce vivipary. Relative humidity, temperature and sunshine hours are some of the climatic factors influencing seed vivipary (Gao *et al*., 2013). Nutritional conditions such as high nitrate nitrogen or low potassium or molybdenum are reported to increase the occurrence of viviparous sprouting.

Variations in the prevalence of vivipary among different accessions of the same crop has been reported. Some mutant genotypes in crops such as tomato, maize, rice and a few others produce seeds that germinate prematurely on the parent plant. They are known as viviparous or pre- harvest sprouting mutants with reduced capacity to synthesize ABA (Fang and Chu, 2008).

Application of foliar nutrient sprays (potassium and molybdenum), chemical induction of seed dormancy through exogenous application of abscisic acid and crop improvement techniques like conventional breeding and hormone engineering are found beneficial in controlling vivipary.

Seed vivipary is, therefore, significant from an agricultural perspective. The lack of seed dormancy with concomitant viviparous germination in crops is a detrimental trait resulting in economic losses as a consequence of lower yield.

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