A STUDY THE MORPHOLOGICAL AND PHYSIOLOGICAL PARAMETERS OF THE ERUCA SATIVA L PLANT

Thesis

Submitted to

For the Degree of

Doctorate of Philosophy

Submitted by

Hema Kushwaha

Enrollment No – MUIT0120038260

Under the Supervision of

Dr. Kanchan Awasthi

Associate Professor

Department of Botany

School of Humanities & Science

Maharishi University of Information Technology

Sitapur Road, P.O. Maharishi Vidya Mandir

Lucknow, 226013

July 2024

Maharishi University of Information Technology

Lucknow 226013, India

Declaration by the Scholar

I hereby declare that the work presented in this thesis entitled " **A Study The Morphological And Physiological Parameters Of The Eruca Sativa L Plant**" in fulfilment of the requirements for the award of Degree of Doctor of Philosophy, submitted in the Maharishi School of Humanities & Science, Maharishi University of Information Technology, Lucknow is an authentic record of my own research work carried out under the supervision of **Dr. Kanchan Awasthi**, **Associate Professor, Department of Botany**. I also declare that the work embodied in the present thesis-

i) is my original work and has not been copied from any journal/ thesis/ book; and
ii) has not been submitted by me for any other Degree or Diploma of any University/ Institution.

Signature of the Scholar

Maharishi University of Information Technology

Lucknow 226013, India

Supervisor's Certificate

This is to certify that **Ms. Hema Kushwaha** has completed the necessary academic turn and the swirl presented by her is a faithful record is a bonafide original work under my guidance and supervision. She has worked on the topic "**A Study The Morphological And Physiological Parameters Of The Eruca Sativa L Plant.**" under the School of Science and Humanities, Maharishi University of Information Technology, Lucknow.

Dr. Kanchan Awasthi
Associate Professor
Department of Botany
Maharishi University of Information Technology
Lucknow

Date:

ACKNOWLEDGEMENTS

We express our sincere gratitude to Maharishi University of Information Technology, Lucknow for providing the necessary infrastructure and facilities essential for conducting this research. We extend our appreciation to the team at the Botany Department for their technical assistance and support throughout the experimental procedures.

Our heartfelt thanks go to my supervisor Dr. Kanchan Awasthi, Associate Professor, Department of Botany for their valuable contributions to the design and execution of various aspects of this study. Their insights and dedication significantly enriched the project.

We are immensely thankful to the participants and volunteers whose involvement was pivotal in the successful execution of the in vivo experiments. Their cooperation and commitment are greatly appreciated.

We acknowledge the funding support provided by Maharishi University of Information Technology, Lucknow, without which this research would not have been possible. Their financial assistance played a crucial role in facilitating the various stages of this study.

Name of the Student

ABSTRACT

Eruca sativa L. is a member of the Brassicaceae/Cruciferae family, often known as rocket, *taramira*, and *arugula*. This is an annual, herbaceous oilseed plant with significant economic value. The plant is utilized as a leafy vegetable due to its peppery flavor, freshness, tartness, and bitterness. The herb has considerable medical benefits. Photochemical research on several portions of *Eruca sativa* have revealed the presence of flavonoid chemicals, alkaloids, cardiac glycosides, and so forth. Rockets are endemic to the Mediterranean area.

In the current study, three types of Rocket plant are used, and hybridization is carried out followed by minute measurements of morphological and physiological data. Morphological criteria include percentage seed germination, seedling morphology, average number of branches, plant height, and days to blossom. Number of stomata per unit area, number of chloroplasts per guard cell, average number of ovules per pistil, and number of seeds per silique. The physiological parameter is rate of transpiration. Certain cytological criteria are also considered, including the mean number of chromocentres and pollen fertility.

Table of Content

Content Details

List of Figure

List of Table

CHAPTER 1
INTRODUCTION

1.1 INTRODUCTION

Eruca sativa L. belongs to family Brassicacea /.Cruciferae, commonly knownas rocket, taramira and arugula. This is an annual, herbaceous oilseed plant of great economic importance. Plant is used as a leafy vegetablefor its peppery flavour, fresh, tart and bitter test. The plant is having the great medicinal value. The photochemical studies conducted on various parts of *Eruca sativa*, reveals the presence of flavenoid compounds, alkaloids, cardiac glycosides etc. Rocket isnative to Mediterranean region.

Rocket, eruca, or arugula (Eruca vesicaria; synonyms: Eruca sativa Mill., E. vesicaria subsp. sativa (Miller) Thell., Brassica eruca L.) is an edible annual species in the Brassicaceae family that is grown as a leaf vegetable for its fresh, acidic, bitter, and peppery flavor. It is also known as garden rocket (in Britain, Australia, South Africa, Ireland, and New Zealand), colewort, roquette, ruchetta, rucola, rucoli, and rugula. E. vesicaria is a classic salad vegetable that originated in the Mediterranean region. (Blamey, 1989; Yaniv 1998)

Rocket, according to historical texts, is an Israeli native plant. Rocket was discovered to be employed as a garden crop and spice in an ancient Israel literary assessment, which included Jewish and Islamic materials from the Middle Ages. Rocket is also a medicinal plant that is used to treat aphrodisiacs, eye infections, digestion, and renal difficulties. This plant contains erucic acid, which is considered a possible future source of industrial oil.

Rocket is also manufactured in Mediterranean nations including Italy, Greece, Moracco, Portgal, and Turkey. In these areas, rocket is also commonly utilized as a garden plant or spice. Accordingto statistics from Turkish StatisticsFoundation (TUIK), plant output in 2010 was expected to be over 4058 tons, which were utilized either fresh in salads or cooked in avariety of recipes.

In addition to its nutritional benefits, the rocket contains powerful phytochemicals, making it valuable in the beauty industry. Rocket is an annual plant that grows to a height of around 20 to 100cm (8 to 40 inches). The leavesare pinnate and deeplylobed, with four to ten little lateral lobes & one huge terminal lobe. The blooms have the characteristic Brassicaceae structure and are grouped in corymbs about 2 to 4 cm in diameter. The petals are creamywhite with purpleveins, or yellow petals with yellow stamens. The fruit is a silique (pod) ranging in length from 12 to 25 mm, with an apical beak & many edible seeds within. This specieshas the chromosomal number2n = 22.

FIGURE 1.1 LEAVES OF ERUCA SATIVA (ROCKET) PLANT

FIGURE 1.2 ERUCA SATIVA (ROCKET) SEEDS

FIGURE 1.3 INFLORESCENCE ANDYOUNG FRUITS OF ARUGULAOR RUCOLA

The term sativa in plant binomial is a Latin adjective derivedfrom satum, supine of verb sero, which means to sow, indicating that plant's seeds are spread in a garden. Rocket may grow on dry, disturbed earth. This plant's roots are sensitive to nematodes. Rocket is a spicy, leafy green vegetable that resembles long-leafed open lettuce. It is currently commercially grown in many regions and may be purchased at supermarkets and farmers' markets. Gargeer is the Indian name for ripe rocket seeds.

Sativa, one of the plant's synonyms, derives latin satum, which means "to sow," implying that the plant's seeds were spread in gardens. Eruca sativa varies from E. vesicaria in that its sepals are early deciduous. Some botanical researchers considered it a subspecies of E. vesicaria, namely E. v. subsp. sativa. Others do not distinguish between the two.(ebge.org.uk)

The English common term rocket comes from French roquette, which is a derivation from Italian ruchetta, a diminutive of ruca, from the Latin word eruca.

The term "arugula" (/əˈruːɡələ/), which is now widely used in the United States and Canada, originated in a nonstandard dialect of Italian. The normal Italian term is "rucola". According to the Oxford English Dictionary, "arugula" first appeared in American English in a 1960 New York Times article by Craig Claiborne, a culinary editor and prolific cookbook writer.

TABLE 1.1 SCIENTIFIC CLASSIFICATION OF ERUCA SATIVA PLANT

Kingdom:	**Plantae**
Clade:	Tracheophytes
Clade:	Angiosperms
Clade:	Eudicots
Clade:	Rosids
Order:	Brassicales
Family:	Brassicaceae
Genus:	*Eruca*
Species:	*E. vesicaria*
Binomial name	*Eruca vesicaria* (L.) Cav.
Synonyms	Arugula, Rocket

1.2 NUTRITIONAL VALUE (PER 100 gm)

Raw arugula is 92% water, 4% carbs, 2.5% protein, and has very little fat. A 100 g (3+1⁄2 oz) reference portion contains just 105 kJ (25 kcal) of dietary energy. It is high in folate and vitamin K, accounting for 20% or more of the Daily Value (DV). Arugula contains 10-19% of the daily value of vitamin A, vitamin C, and the minerals magnesium, calcium, zinc, and selenium.

Energy -	105 KJ(25 kcal)
Protein -	2.6 gm
Carbohydrates -	3.6 gm
Fat -	0.6gm
Sugars -	2.0gm
Dietary Fiber -	1.6gm

TABLE 1.2: VITAMINS

Vitamins	Quantity	%DV†
Vitamin A equiv.	119 μg	13%
beta-Carotene	1424 μg	13%
lutein zeaxanthin	3555 μg	
Vitamin A	2373 IU	
Thiamine (B1)	0.044 mg	4%
Riboflavin (B2)	0.086 mg	7%
Niacin (B3)	0.305 mg	2%
Vitamin B6	0.073 mg	4%
Folate (B9)	97 μg	24%
Vitamin C	15 mg	17%
Vitamin E	0.43 mg	3%
Vitamin K	108.6 μg	4%

TABLE 1.3 MINERALS

Minerals	Quantity	%DV
Calcium	160 mg	12%
Copper	0.076 mg	8%
Iron	1.46 mg	8%
Magnesium	47 mg	11%
Manganese	0.321 mg	14%
Phosphorus	52 mg	4%
Potassium	369 mg	12%
Sodium	27 mg	1%
Zinc	0.47 mg	4%
Water	91.7 g	

1.3ECOLOGY

E. vesicaria is endemic to Southern Europe, North Africa, and the Middle East. Arugula is a widespread but dispersed invasive plant that is abundant and harmful in the Sonora deserts of Arizona and California. The species usually thrives on dry, disturbed terrain. It provides food for the larvae of several moth species, including the garden carpet. Its roots are prone to nematode invasion.(smartgardener.com)

1.4 CULTIVATION

E. vesicaria is a pungent, leafy green vegetable that resembles a longer-leaved, open lettuce. It is high in folate, vitamin K, vitamin C, and potassium.(nutritionData.com) In addition to the leaves, the blooms, juvenile seed pods, and fully developed seeds are edible.

Grown as an edible widely consumed herb in Italy since the time of Romans, arugula has been cited by various ancient Roman classical authors as an ecstasy, most famously in a poem long assigned to the famous first century Rome poet Virgil, Moretum, that includes the line: "et Venerem revocans eruca morantem" ("and the rocket, which revives sleepy Venus [sexual desire]"), and in the Ars Amatoria of Ovid. (Upton et al., 2010; Wright 2001; Virgil 1916; Ovid 2008). According to some sources, this is why cultivating arugula was outlawed in monasteries throughout the Middle Ages.(Padulosi et al., 1997). Nonetheless, Charlemagne decreed that the plant be included among the 802 pot plants appropriate for garden cultivation.(Hellen 1970) According to Gillian Riley, editor of the Oxford Companion to Italian Food, because of its reputation as a sexual stimulant, it was "prudently mixed with lettuce, which was the opposite" (i.e., soothing or even soporific). Riley goes on to say that "nowadays rocket is enjoyed innocently in mixed salads, to which it adds a pleasing pungency" (Gillian Riley 2008), however Norman Douglas believed that "salad rocket is certainly a stimulant".

The plant was typically harvested from the wild or cultivated in household gardens with herbs like parsley and basil. Arugula is currently commercially farmed in a variety of locations and can be found in supermarkets and farmers markets across the world. It has been naturalized as a wild plant in temperate zones all over the world, including northern Europe and North America. In India, ripe seeds are referred to as "Gargeer". The Arabic name جِرْجِير (jirjīr) refers to the plant's new leaves.

Mild frosts slow the plant's development and cause the green leaves to become crimson. If the weather is warm, plants reach full growth in 40 to 50 days.

1.5 CULINARY

Raw arugula has been used in salads since ancient Rome. It is frequently used as a garnish on pizzas at the conclusion of or shortly after baking. In Apulia, southern Italy, arugula is cooked to make the pasta dish "cavatiéddi," "in which plenty of coarsely chopped rocket are added to pasta prepared with a homemade reduced tomato-based sauce and pecorino," as well as in many recipes in which it is chopped and added to condiments and cooked foods or in a sauce (made by frying it in olive oil with garlic). It is often used as an additive with cold meats and fish. Throughout Italy, it is served as a salad with tomatoes and burrata, bocconcini, buffalo, or parmesan cheese. "Rucola" is used in "straccetti" in Rome, a meal of thin slices of steak with raw arugula and mozzarella cheese.

In Turkey, the plant is eaten raw as a side dish or salad with fish, or with a sauce made of extra virgin olive oil and lemon juice. In Slovenia, arugula is frequently paired with cooked potatoes or used in soups.

Eruca seeds are crushed to produce taramira oil, which is used in pickling and, after age to eliminate acridity, as a salad or cooking oil. The seed cake can also be used as animal feed. Since the 1990s, arugula has gained popularity in America, particularly in trendy restaurants and metropolitan regions.

1.6 UTILIZATION

Fresh rocket leaves give a peppery crisp flavor to a variety of foods and are commonly used as salad veggies across the world. Rocket plant has grown in popularity in recent years as consumers seek a handy, healthy, and easily available product. Fresh rocket leaves are very alkaline and antioxidant-rich. Certain phytochemicals are also found, with protective and disease-preventing qualities.

It inhibits carcinogenic effects of estrogen & protects against prostate, breast, cervical, colon, & ovarian cancer. This plant can also prevent the development of cancer cells and have cytotoxic effects on them. This plant has high levels of vitamin A and flavonoid chemicals. These flavonoid molecules found in rocket can help prevent humans from skin, lung, and mouth cancer. These flavonoid molecules are regarded a significant characteristic of the plant since they operate as an anti-allergic, anti-cancer, antioxidant, anti-inflammatory, and antiviral material.

Rocket also has a high concentration of folates, or folic acid. Consuming this plant's leaves during the conception phase may help avoid neural tube abnormalities in newborn kids.The plant contains vital minerals such as calcium, magnesium, potassium, sulfur, iron, phosphorus, and selenium. The plant is renowned asa medicinal herb & is used as anaphrodisiac, to treat eyeinfections, digestion, & renal issues.

1.7 ORIGIN

Although there is consensus on the evolutionary origins of numerous Brassica species, including rocket. To some extent, evolutionary events may be reconstructed using geographical, ecological, cytological, historical, and archeological information.

The rocket plant, which is extensively used as asalad vegetable, isnative to Mediterranean area, stretching fromMorocco & Portugal in west toSyria, Lebanon, Egypt, & Turkey in east. A review of ancient Israeli literature was done, spanning Jewish, classical, & Islamic texts up to Middle Ages. Itwas discovered that rocketwas employed as a spice, medicinal herb, & garden produce. In northwestern India, rocket is regarded as a key oilseed crop.

1.8 INTERSPECIFIC AND INTERGENERIC HYBRIDIZATION

Intergeneric and interspecific hybridization is an essential approach of plant breeding. It is also a useful experimental technique for studying the genome homology of phylogenetically related taxa, species, and their origins and evolution. Hybridisation combines the features of genetically diverse and distant species and genera that diverged long ago throughout the evolutionary process, resulting in new segregation hybrid progenies in subsequent generations. This is the location where plant breeders still choose hybridization techniques over more contemporary ways of plant breeding. Several issues have arisen during attempts at interspecific or intergeneric hybridization. The most significant difficulties are

1. The failure of pollento germinate on stigma and penetrate entire length of the style, affecting fertilization.
2. Hybrid embryos are aborted owing to embryo-endosperm imbalance. To overcome the first incompatibility hurdle, various researchers are said to have employed

I. Chemicals administered to the ovary (Hosoda 1961, Nakai 1971)

II. Repeated or mixed pollination (Sarashima 1964), and

III. Styleexcision or grafting (Hosodaet al. 1963, Nakai 1979). The problems of salvaging embryos have been handled by using in vitro embryo culturing techniques (Nishi et al., 1962, 1970, Herbard et al., 1972) and culture of excised ovaries of hybrids in vitro (Inomata 1976, 1978). Kamya and Hinata (1970 b) built on previous successes to successfully employ in-vitro fertilization. Kamaya and Takahashi (1972) demonstrated protoplast fusion, which raised the potential of future extensive hybridization.

Alloplasmicmale sterile rocket breeding lineswere created byintergeneric hybridizationwith CMS (Cytoplasmic male sterility) - Brassica oleraceae, followed by recurrentbackcrosses to establish breeding value. Manual crossings and embryo rescue resulted in fiveamphidiploid F1 plants (2n = 2x = 20CE) with an intermediate habit. After pollination with rocket parent, the plants had no seed set and were fully male sterile. After colchicine treatment, allotetraploid F1-Hybridplants (4n = 4x =40 CCEE) were produced, and to select alloplasmic diploid Eruca sativa lines, plants were backcrossed 6 times with pollen from Eruca sativa parent. The ploidy level was determined using chromosomal analysis and cytometry.

During anther development, premeiotic and postmeiotic defects were discovered. In the alloplasmic Eruca sativa plant, compared to CMS - cauliflower donor. There were no other incompatibilities seen b/w CMS-containing cybrid cytoplasm & Eruca sativa nucleargenome. Eruca sativa alloplasms were eventually shown to be diploid, having 2n = 2x = 22 chromosomes. The plant displayed full male sterility while restoring female fertility. The produced lines may be used directly for hybrid rocket salad breeding.

1.9 INTERBREEDING AND HETEROSIS

1.9.1 INTERBREEDING

Interbreeding refers to the mating of closely related individuals in a community. Inbreeding allows us to quickly study the genetic differences between allogamous populations of animals. Increased homozygocity disrupts the genetic equilibrium of a population, resulting in a number of reproductively independent lineages. In cross breeding populations, inbreeding causes an overall loss in vigor and output. (Shull 1911, 1952; East and Jones 1919; East 1936; Lerner 1954; Mathur 1955, Brewbaker 1964; Allard 1960). In the hands of plant breeders, it has shown to be an effective tool. Following this strategy, extremely homozygous lines may be grown by forced selfing for several years and then crossed to create hybrids, which frequently display hybrid vigor.

The combining ability of inbred lines determines the degree of heterosis. Through crossover, vigor lost during inbreeding is not only recovered, but frequently outperforms the original populations. A variety of genetic phenomena, including self-incompatibility, genetic regulation of chromosomal behavior, and other biological processes, may be examined effectively using inbred lines.

1.9.2 HETEROSIS

Shull was first to introduce term 'heterosis' in1914. Heterosis may be described as superiority of an F1hybrid above both parents interms of yield or other characteristics.It is the opposite of inbreeding. It is a genetic manifestation of the favorable effects of hybridization. Heterosis is often shown as anincrease in vigor, size, growthrate, yield, and a variety of other traits. Frequently, the superiority of F1 is evaluated above the average of 2 parents or middle parent. It is considered heterosis if the hybrid outperforms the mid parent. 'Hybrid vigor' is a synonym for heterosis.

Understanding its genetic nature requires knowledge of the factors driving the full manifestation of heterosis throughout hybrid plant growth.Because of its evident importance in crop development initiatives, heterosis continues to be one of the most investigated genetic phenomena. Although several ideas and hypotheses have been proposed over the years, it is astonishing that its genetic nature is still unknown (Davenport 1908; Jones 1918; East & Shull 1908). When inbred rocket lines were crossed, the F1 hybrids showed not only increased vigor and growth, but also a considerable increase in total plant and seed count. The hybrids had luxuriant vegetative development, and some even outperformed the original varietal populations (Narbut 1961; Dayal 1974, 75).

So far, the inquiry has revealed that heterosis in complex characters is a summary of the influence of simple character inheritance. Furthermore, hybrids' development conditions have a considerable impact on the emergence of heterosis. Heterosis is commercially employed as hybrid or synthetic variations.It is mostly employed in cross-pollinated crops. However, attempts have beenmade & arebeing made to use heterosisin the breeding of some self-pollinated crops like wheat & barley, but sofar, these attempts havenot proven successful Because self-pollinated crops, particularly grains, produce fewer seeds per fruit, it is difficult to utilize bajra, cotton, asexually propagatedcrop species, & fruit trees (Allard 1960, Pal & Sikke 1956, Singh 1962, Sinha & Khanna 1975).

1.10 SELF - INCOMPATIBILITY SYSTEM

Self-incompatibility is described as a plant's inability to produce viable gametes when self-pollinated (Brewbaker 1957a,b). It has recently gained prominence in genetics because to its implications in plant physiology, biochemistry, plant breeding, and evolution.Several facets of the self-incompatibility system havebeen discussed elsewhere(Crowe 1964, Lewis 1954, Linskens1965, Arasu 1968, Lundqvist 1965,Sears 1937, Surikow 1971, Heslop-Harrison 1975, Charlesworth & Charlesworth 1979).

There are three basic forms of self-incompatibilitysystems in angiosperms: gametophytic (GSI), sporophytic (SSI), & heteromorphic (HSI). Brassicacea members investigated thus far have a sporophytic system of self-incompatibility (SSI). In an SSI self-incompatibility system, incompatibility is regulated by a single locus S with several allelic series that can work independently or exhibit various sorts of dominance relationships in determining pollen behavior. In contrast to GSI, the genotype of the diploid parents determines pollen behavior.

In general, GSI has binucleate pollen grains, whereas SSI has trinucleate pollen grains. Self-incompatibility results from the stopped development of the pollen tubes in the pistil, which involves an interaction b/w haploid pollen tube & diploid pistil cells. Fertilization is possible only when the pollen grains and pistils have different alleles. The existence of aself-incompatibilitysystem in Brassicaceae was documented by Stout (1920), Sears (1937), Bateman (1965), Tatebe (1957-58), and Sampson (1957).

1.11 POLYPLOIDY

Polyploidy refers to all naturally occurring and induced differences in the number of genomes. In other words, polyploidy refers to any occurrence in which the constant number of chromosomes in a species' DNA changes. It has been extremely important in plant breeding and evolution. Polyploids account for over half of the most significant cultivated plants. Polyploidy has been observed to arise spontaneously in diploid populations of plant species.

1.12 OBJECTIVES OF THE STUDY

1. The project aims to collect information on various Eruca Sativa l. plant kinds in India from New Delhi.
2. Analyze plant morphology and physiological factors of Eruca Sativa l. plant
3. Analyzing Various Eruca Sativa l. plant hybridization and heterosis.
4. A few cytological variables are also investigated to determine heterosis.

1.13 PROPOSED CHAPTERIZATION OF THE STUDY

Chapter1	Introduction
Chapter2	Review of related literature
Chapte3	Research methodology
Chapter4	Observation and result discussions
Chapter5	Findings and Conclusion

CHAPTER 2
REVIEW OF LITERATURE

MA EI - Missiry and AM EI Gindy (2000) investigated how rocket seed oil alleviated alloxan-induced diabetes mellitus & oxidative stress inrats. Rocket seed oil is tested for prevention & treatment of diabetes mellituusing alloxan injection.

Mitswo Miyazawaet al. (2002) investigated components of essentialoil extracted from Eruva sativa leaves.

Leopold Jirovetz and David Smith (2002) analyzed Eruca sativa SPME Headspace Leaf Samples Using GC, GC-MS, & Olfactometry. More than 50 constituents of the Eruca atmosphere have been identified as essential volatiles, which explain for the salad leaves' characteristic herbal, vibrant green, nutty and almond-like, Brassicaceae-like (similar to broccoli, cabbage, and dijon), and horseradish-like perfumes.

J. M Pita Villamil et al. (2002) investigated seed germination and the timing of rocket seed collecting. They also noted the value of rocket as a leaf & oilcrop, particularly as a fourth-generationvegetable.

M. Yasin Ashraf and G. Sarwar (2002) investigated the physiological relationships between water and mineral content in various Brassicaceae members, as well as their salt tolerance capability. In their experiment, scientists chose six cultivars from various brassica species to test for salt tolerance capability.

EV Sastry (2003) investigated the improvement of Eruca sativa. According to him, there are just a few types of this plant, thus genetic advancement is limited. They highlighted that Rocket possesses beneficial features, including disease resistance, that may be passed on to B. juncea and Brassica campestris, both of which are significant crops.

Seema Mahmood and Asma Hussain (2004) investigated the comparative performance ofBrassica napus & Eruca sativa in deficiency circumstances. They investigated the morphological and phonological features of B. napus and E. sativa in response to drought. Furthermore, species responses varied in terms of tolerance to various drought regimes.

Jessica Barillariet al. (2005) investigated the action of pure glucoerucin, a dietary secondarymetabolite of rocket. They investigated many health-promoting substances such as caratenoids, vitamin C, fibers,flavonoids, & glocosinolates.

IS Fazil et al. (2005) investigated the interaction of sulphur and nitrogen in growing seeds in terms of lipid accumulation, acetyl-CoA, and acetyl-CoA concentration. They conducted field tests to investigate the interaction of sulphur and nitrogen on fat formation.

Sun-Ju Kim and Gensho Ishii(2006) investigated antioxidant & glucosinolate profiles of rocket salad seeds, leaves, and roots. Rocket salad yielded a substance known as methoxyglucobrassicin.

S Larran et al. (2006) investigated the influence of Perenospora parasitica on rocket, which was originally identified in Argentina. In the autumn and winter of 2005, rocket plants had severe foliar disease infections.

M. Sarwar Alam et al. (2007) investigated Rocket's antioxidant activity and found that it protects against mercuric chloride-induced kidney damage. Rocket has a strong reputation for treating renal illnesses and is commonly utilized in folkloric medicine.

Richard N Bennett et al. (2007) investigated the measurement and identification of glucosinolates in sprouts fromwild rocket and saladrocket. They wanted to investigate how geographical origin impacts glucosinolate content in rocket species.

Ellahi Bukhsh et al. (2007) conducted research on Carthamus oxyacantha, Eruca sativa, and Plantago ovata, estimating nutritional value and trace element concentration. In their current investigation, they discovered that these herbs have medical effects such as antihyperlipidemic, antihyperglycemic, antinephrolithatic, and hepatoprotective. They investigated the estimate of trace elements and nutritional value in these plants.

DK Sharma et al. (2007) conducted research on nutrition management in oleiferous rocket salad to evaluate sugarcane-based industrial waste and jatropha litter fall.

Tim Nielsen et al. (2008) investigated the source of unpleasant odors in packaged rucola. They focused on the collection of off-odours in the packing.

Tim Nielsen et al. (2008) investigated the source of unpleasant odors in packaged rucola. They looked at how off-odours accumulated in the packing headspace.

SS Manohar and KC Sharma (2008) investigated character association analysis and genetic diversity in rockets.

N Randhawa and SK Sharma (2008) investigated soilamendment using Brassica rapa,Brassica juncea, Brassica napus, & rocket plants to prevent root knot nematodes in tomato nursery beds.

Saleh Alqasoumi et al. (2009) investigated Eruca sativa for possible stomach ulcer prevention. His goal was to evaluate Rocket's stomach anti-ulcer capabilities by observing artificially produced gastric secretion and ulceration in albino rats.

Salim Khan and F. Al-Qurainy (2009) investigated rocket seed germination and found that sodium azide has a mutagenic impact. Sodium azide, a chemical mutagen, is commonly employed to increase crop quality and output.

S. Nicola et al. (2009) investigated the filling quantity, shelf life temperature, and qualitative & physiological responses of little processedrocket topackage products. Their experiment was designed to investigate the influence of storage temperature (4 C, 12 C) and package fillingamount (50 g, 100 g) on the physiology & quality of minimally treated rockets throughout a 10-day shelf life.

Mohammed H Chakrabarti and Rafiq Ahmad (2009) investigated the feasibility of producing biodiesel from rocket oil, the least acceptable edible oil. In the current investigation, bio diesel made from edible oils of soya bean or canola was discovered to have more or less equivalent storage, handling, and combustion qualities.

Fahad Al-Qurainy (2009) investigated the effects of sodium azide on rocket yield and growth.

Gautam Kumar et al. (2009) investigated salt stress in Brassica species and their physiological responses, which revealed a substantial association with transcript abundancefor SOS pathway-relatedgenes.

Jing Jin et al. (2009) investigated chemoprotective potential of rockets and the phytochemical content of plants. They evaluated a variety of phytochemicals, including glucosinolates and flavonoids, which are abundant in Brassicaceous crops.

Yasemin Ozdener et al. (2010) investigated influence of zincon biochemical parameters & growth in seedlings of Eruca sativa L. Under controlled settings, rocket seedlings were treated with various Zn concentrations.

M Kadri Bozokalfa and Dursun Esiyok (2011) investigated and evaluated the phenotypic diversity and spatial variation of farmed and wild Rocket plants. The goal of thisstudy was to identify phenotypic diversity & relationships amongEruca sativa genotypes.

Helana Michale et al. (2011) investigated the biological activity as an anticancer drug in vitro, as well as the chemical contents of fresh leaves. In phytochemical studies, an aqueous extract of Eruca sativa fresh leaves was shown to contain nine natural flavonoid components.

WT Kasem et al. (2011) investigated the seed coat & seed morphological sculpturing of 32Brassicaceae species. LM and SEM were used to evaluate 32 Brassicaceae species and their seed exomorphic characteristics.

Mohamed H AL - Whaibi et al. (2012) investigated the growth performance and photosynthetic pigment status of rockets, as well as effect of plantgrowth regulators. To increase rocket plant performance, the viability of using plant growth regulators(kinetin GA3, spermidine, & napthaline acetic acid)was investigated.

Kenneth J Berba and Mark E Uchanski (2012) investigated microgreens and their postharvest physiology.

Abdul Samad Mumtaz (2013) investigated the geneticdivergence in Rocket (Eruca sativa L.)germplasm using quantitative & qualitative characteristics. They selected 100 Rocket genotypes from distinct eco-geographic locations in Pakistan and examined their phenotypicdiversity for 20 quantitative & five qualitative features.

Candida Vannini et al. (2013) investigated the morphological & proteomic responses ofEruca sativa when exposed toNanoparticles (AgNPs) orSilver Nitrates. In commercial items, silver nanoparticles are commonly employed. To better understand the mechanism behind plant responses toAgNPs & to distinguish b/w particle-specific & ionic silver impacts, we investigated the morphological and proteomic alterations caused in Eruca sativa inresponse to AgNPs $AgNO_3$.

Azhakan Suma et al. (2013) investigated influence of relativhumidity in assessing heterogeneity in storage behavior, processing, and storage seeds in Eruca sativa. The behavior of several Brassica species, as well as the heterogeneity in seed storage, was investigated.

Gonca Keser (2013) studied the effects of wastewater irrigation on the physiological parameters and heavy metal concentration of Lepidium sativum L. and Eruca sativa. The major objective of this study was to evaluate the physiological characteristics and heavy metal concentrations of Lepidium sativum L. and Eruca sativa that had been irrigated with municipal wastewater for twenty days.

Zena F Hussein (2013) investigated effects of rocket leafextract on fertility of male albino mice. They devised the current study tolook closely at effect of rocket leaf extract on spermactivity, mortality & abnormalities,histological alterations in testes, and testosterone levels in albino mice.

Gupta et al. (2013) investigated rocket plants' defensive response to the fungal disease Alternaria brassiciola, including the development of β-1,3-glucanase & chitinaseactivities. Plants have evolved several methods to combat the majority of possible microbial infections and illnesses, according to their findings.

AK Indoria et al. (2013) investigated the phytoextractability of Cd in soil as modified by sewage sludge and farmyard manure in several oilseed species.

Gajra Garg (2014) investigated the botanicaldescription, cropimprovement, & therapeutic characteristics of Eruca sativa L. Her study involved the molecular characterization and creation of genotype-specific SCAR markers in Eruca sativa L.

Luke Bell & Carol Wagstaff (2014) investigated myrosinasehydrolysis products, glucosinolates, & flavonols identified inRocket. Rocket species have a high content of glucosinolates and flavonoids. Rocket has several health advantages when consumed on a daily basis.

Ushahra Jyoti et al. (2014). Worked on the degradation of rocket seeds. They conducted a comparison examination between seeds and leaves. Their research centered on function of oxidative stress & antioxidantdefense system.

BL Jat and ML Jakhar (2014) investigated taramira under three environmental circumstances and analyzed the phenotypic path co-efficiency.

Ushahra Jyoti and CP Malik (2014) conducted research on the antioxidant defense system in degraded rocket seed and the function of oxidative stress.

Haroon Khan and Murad Ali Khan (2014) investigated Eruca sativa's urease inhibitory and antiulcer properties. This studyaims to investigate and understand influence of urease activity in vitro.

Yuan Zhi et al. (2015) investigated early seedling development in rockets and effects of heavymetals on seed germination. They investigated negative health repercussions for all living forms caused by the buildup of heavy metals in soil and water owing to human activity.

Jalal Jalilian and N. Khaliliaqdam (2015) investigated various temperatures and their effects on rocket germination rate.

Prabhat Singh et al. (2015) investigated numerous rocket components and their genetic variability for grain yield.

E. Mangwende et al. (2015) conducted research on Albugo candida, the organisms responsible for rocket white rust. Typical white rust signs were found in two commercial garden rocket crops grown in South Africa throughout the winter.

Muhammad Aqeel Kamran et al. (2015) investigated effectof rhizobacteria inoculation oncadmium (Cd) absorption by rocket plants, which has a growth-promoting effect. The current investigation was meant to screen for varied cadmium levels & their ability to deal withCd absorption fromsoils, rocket plant nested possessions, and Pseudomonas putida (ATCC 39213).

Idress Al Gehani et al. (2016) investigated the development and physiological processes of rockets cultivated in salinity conditions, as well as the effect of soil amendments.

B. Nejadhasan et al. (2017) investigated the germination of rocket seeds under various environmental conditions. He carried out this experiment to see how environmental parameters like as water potential, salinity, temperature, and planting depth affect germination.

Sandeep Kumar et al. (2017) investigated rapeseed mustard resistance to the mustard aphid, Lipaphis erysimi, as well as its physical and biochemical properties.

Lalit Kishore, Navpreet Kaur, and Randhir Singh (2018) investigated advanced glycation end products, formation of excessive reactive oxygenspecies, & cellularapoptosis, which are implicated in pathophysiology ofdiabetic neuropathy.

Agnese Gugliandolo et al. (2018) conducted research on the seed extract, a wonderful natural substance capable of combating neuroinflammation. This plant contains nutrients that can have a positive impact on your health.

Abdel Wahab M. Mahmoud et al. (2018) investigated the influence of nano iron & nano zinc combined with organicmanure on the sulphur content of rocket essential oil. They conducted an experiment in an open field to assess effects of nano iron, nano zinc, chicken manure, and combinations thereof on fresh weight and seed production, photosyntheticrate, morphology, transpirationrate, & chemical components reflected in macro & micro elements.

Dalia G Gabr (2018) investigated the taxonomy, identity, and importance of brassicaceae fruit and seed coats. Fruit, seed morphology, & seed coatsculpturing were observed in ten species from nine genera and five tribes of Brassicacea.

Anam Fatima et al. (2018) investigated the authenticity of oil-producing seeds using scanning electron microscopy as a technique. They found that this plant is utilized internationally for a variety of uses, and that increased demand leads to adulteration, resulting in increasing exploitation of natural resources.

Angeliki Kavga et al. (2018) investigated the development and physiological features of rocket plants grown beneath solar panels, as well as lettuce.

Sawsan Kadhim Mashi and Dina Saadoon Dheyab (2018) investigated the impact of rocket leaf extract onosteoporosis produced by phosphoricacid and pathological alterations in bone in adult malerabbits.

Yong-Joon Choi et al. (2018) investigated the downy mildew pathogen of arugula, Hyaloperonospora erucae sp. nov.

Iiona Plaksenkova et al. (2019) investigated the growth and development of rockets as well as the impacts of Fe304 nanoparticles. Plants respond to stress by employing a range of gene regulation systems.

Lovely Mahawar and Gyan Singh Shekhawat (2019) investigated the role of EsHO 1 in reducing NaCl-induced oxidative stress in Eruca sativa seedlings, as well as the relationship between ROS, antioxidants, and HO 1.

Noor S Jaafar et al. (2019) investigated the pharmacognostic and pharmacological aspects of medicinal formulations. They discussed the several phytochemicals found in Rocket, including flavonoids, phenolic acids, tarpens, carotenoids, tannins, glycosides, saponins, sterols, alkaloids, & other secondary metabolites.

Oz Barazani et al. (2019) investigated smell and natural diversity in flower color in rocket plants, which influences honey bee pollination behavior. Flower colours differ between desert and Mediterranean populations in Israel.

Muhammad Shakeel et al. (2019) investigated effect of relative abundance in Erucasativa Mill. on insect pollinator diversity.

Ajay Kumar et al. (2019) focused on improving the quality of flax growth and output in Uttarakhand, Tarai area, India, using integrated nutrient management.

Mona Adel El-Wakeel et al. (2019) investigated the bioherbicidal activity of rocket. Their research demonstrates how to explore the allelopathic potential of rocket aqueous extract of fresh shoot as a natural bioherbicide for controlling Beta vulgaris and Phalaris minor weeds, as well as its influence on Pisum sativum yield and growth features.

Sadia Afsar et al. (2020) assessed salt tolerance in Eruca sativa accessions utilizing morpho-physiological characteristics. The current study aims to examine salt stress tolerance in 25 E. sativa accessions collected from diverse geographical regions in Pakistan.

Najla Altwaijry et al. (2020). The goal was to examine oxidative stress and testicular toxicity through the therapeutic effect of rocket seeds in therapy.

Esmaeil Bakhshandeh et al. (2020) investigated effects ofenvironmental conditions on rocket seed germination & seedling growth usingmathematical models.

Catello Pane et al. (2020) investigated the drench application obioactive potato leaf phytochemicalextracts to control rhizoctonia damping off of rocket. He discovered that plants have a vast diversity of secondary metabolites that play an important part in defensive mechanisms.

Francesca Bonvicini et al. (2020) examined the impact of Lactobacillus acidophilus enhanced with rocket seed extracts on the intestinal barrier. Lactic acid bacteria have a favorable influence on intestinal function.

Asif Ullah Khan et al. (2020) conducted research on rocket seed for the manufacture of organic fertilizer. They investigated the favorable impacts on soil characteristics and crop quality. They conducted two field experiments to assess the impact of organic fertilizers on soil fertility.

Maryam Zafar-Pashanezhad et al. (2020) investigated the genetic variation of rocket plant genotypes as reflected by ISSR molecular markers and agromorphological parameters.

Franklin EM Santiago et al. (2020) investigated differential selenium tolerance in arugula and lettuce on a biochemical basis.

Khushboo Khator et al. (2020) investigated association b/w two genotypes & antioxidant in terms of physiologically and morphological changes.

Binish Khaliq et al. (2021) investigated detailed functional characterisation and structural insights in rockets. A strong napin protein derived from rocket salad seeds has been extensively studied.

Naif Ali Elmardy et al. (2021) investigated and analyzed Rocket's photosynthesis under various light intensities, quality, and photoperiods.

Reham M Abd-Elsalam et al. (2021) investigated oxidative stress in rocket seed extract, apoptosis, and the upregulation of Bcl-2 expression. The current investigation was based on an LC/MS analysis of total the ethanol extract in rocket.

Antonio Nanetti et al. (2021) investigated Brassica nigra seed meals and the management of fake Nosema ceranae infections inApis mellifera. Nosemaceranae is a parasitethat is widely distributed. These parasites cause nonsemosis Type C in honey bees.

Jolan Jamal et al. (2021) investigated rocket development factors under supplementary LED illumination utilizing the internet ofthings. The Internetof Things (IoT) is utilized to monitor several growth characteristics of rocket plants grown under supplementary LED illumination in a greenhouse.

M Vahabi Mashhoor et al. (2021) investigated the elm leaf bettle Xanthogalerucaluteola and the antifeedant activity of an arugula oil nanoemulsion formulation.

Ebisa Olika Keyata et al.(2021) investigated the phytochemical content, antioxidant activity, & functional qualities of Raphanussativus L., Eruca sativaL., and Hibiscus sabdariffa L. plants grown inEthiopia.

Arthur Ferrari Teixeira et al. (2022) investigated the chemicalanalysis of Eruca sativa ethanolic extract & its effects onhyperuricaemia. They found a hypouricaemic response in hyperuricaemic Wister rats treated with ethanoloic extract at a level of 125 mg/kg.

Sheharyar Khan et al. (2022) investigated the influence of osmotic stress on seedgermination, temperature, & seedling development in Eruca sativaMill. They concluded that germination models are useful for observing dormancy periods, crop management, and forecasting emergence timeframes.

HS Gadow et al. (2022) conducted experimental and theoretical investigations on rocket seed extract. This study included electrochemical, chemical, electrical frequency modulation, potentiodynamic polarization, and electrochemical impedance spectroscopy methods.

Mustafa Cuce and Asiye Sezgin Muslu (2022) studied role ofexogenous SNP in alleviating effects of PQ-mediatedoxidative stresson rocket plantlets cultivated in MS basalmedium.

Maria Cristina Sorrentino et al. (2023) state that ionizingradiation (IR) & its effect onorganisms are increasingly being explored owing to its potentialapplications in grown plants. We investigated effects of ionizing radiation onEruca sativa by examiningplants developed from irradiatedseeds (1 and 10 Gy) under hydroponics. We assessed a variety of morphophysiological parameters as well as genotoxicity. Radiation exposure resulted in significant variation in morphophysiological parameters, indicating lower plant vigor. Shoot length and leaf count were substantially greater in 1 Gy-treated samples, whereas root length was significantly higher in 10 Gy-treated plants. The number of stomata increased considerably with IR exposure, however pigment and Rubisco concentrations decreased due to radiation stress.

Sona S. El-Nwehy et al. (2023) found that applying all three components foliarly (CMS + Zn + B) resulted in the highest seed production (184.6 g/m2) and oil content (675.3 kg/ha). In compared to the control group, the macronutrient content of N, P, K, Mg, and Ca increased by 34.4%, 56%, 42%, 45%, and 39% in seeds treated with these components, respectively. Furthermore, carbohydrates, proteins, phenolics, flavonoids, and antioxidants all rose by 24%, 34%, 21%, 43%, and 28%, respectively, as compared to the control group. Gas-liquid chromatography analysis found ten components in the seed oil, with more unsaturated fatty acids ranging from 81.28% to 92.28% and lower saturated fatty acids ranging from 6.72% to 8.21%. As a consequence, foliar spraying with CMS, zinc, and boron can help minimize salt impacts on Rocket plants cultivated under saline water irrigation circumstances while enhancing growth, yield, extraction of oils, and nutritional content such as total carbs, proteins, and nutritional levels.

Ayşe ÖZKAN et al. (2024) investigated how chitosan treatment affects rocket production and quality. The "Bengi" rocket type was used as a plant stuff, and chitosan was sprayed into the foliage at four different doses (0 (control), 75, 150, and 300 ppm). The yield values were between 1691 and 1914 g m-2, plant height above 24.33 and 27.92 cm, and leaf width between 4.56 and 5.71 cm across all applications. Total dry matter, chlorophyll, total phenolics, vitamin C, and antiradical activity levels ranged from 7.71% to 8.68%, 34.15 and 36.68 SPAD, 104.67 and 180.84 mg 100 g-1, 126.63 and 143.51 mg 100 g-1, and 63.77% and 71.87%, correspondingly.

CHAPTER 3

RESERCH METHOLOGY

3.1 MATERIAL

The materials employed in the current study included three types of Eruca sativaL. plant, which are extensively distributed across our country and the local region of our state (Uttar Pradesh). A brief description of each variety is provided below. Investigations were conducted at the Laboratory of Botany DepaGNTent, MUIT Lucknow.

3.1.1 LOCAL VARIETY GARGEER (LVG)

Spherical dark brown seeds, plants from 20 to 100 cm long, strongly sharply lobed leaves with four to ten little peripheral lobes and a large terminal lobe, corymb-shaped flowers 2-4 cm in diameter, petals creamy white or golden purple veined, and stamens yellow.The plant is massively branched. The fruit, a siliqua, is 12-25 mm long and bears an apical beak containing several seeds.

3.1.2 GREATER NOIDA TARAMIRA (GNT)

Plants range in length from 30 to 120 cm, with deeply pinnately lobed leaves that have six to fourteen little lateral lobes and one huge terminal lobe. Flowers are 2-4 cm in diameter and form a corymb. Petals are creamy white or golden-purple veins, while stamens are yellow. The fruit, a siliqua about 12-25 mm long, contains an apical beak containing many seeds.

3.1.3 LUDHIANA COMPOSITE TARAMIRA (LCT)

The plant has spherical dark brown seeds, is 20 to 110 cm long, and has deeplypinnately lobed leaves withfour to fourteen little lateral lobes & a broad terminal lobe. The flowersare 2-4 cm in diameter and grouped in corymb. The petals are creamywhite or yellow withpurple lines, & stamens are yellow.The fruit ranges from 12 to 25 mm in length and has an apical beak carrying several seeds.

FIGURE 3.1 ROCKET PLANT GENERAL VIEW

FIGIURE 3.2: MORPHOLOGICAL OBSERVATIONS OF THE EXPERIMENTAL PLANT

FIGURE 3.3: PROCESS OF HYBRIDIZATION

3.2 METHODOLOGY

3.2.1 MORPHOLOGICAL PARAMETERS

3.2.1.1 PERCENT SEED GERMINATION

Seed germination trials were conducted at room temperature. 100 seeds from each kind were planted in ten separate petridishes. Blotting paper was placed at the base and soaked with distilled water at regular intervals. There were no fertilizers or chemicals utilized in the soil. On the seventh day following seeding, percentage seed germination was measured.

3.2.1.2 SEEDLING MORPHOLOGY

Seedling morphology was investigated by sowing 200 seeds of each type in various iron trays, filling them with homogeneous soil and irrigating them at regular intervals. To investigate the shape of the hypocotyl, 100 mature seedlings from each variety and F1 intervarietal hybrids were randomly chosen. After the first real leaf appeared, they were removed from the soil. This happened 10 to 15 days after seeding.

At this stage, the seedlings were pressed for a week in a filter paper booklet. The length ofeach seedling's hypocotyl was measuredusing a scale & thread. At the same time, length & breadth of cotyledons weremeasured using a division & scale. Mean cotyledon was scored by multiplying length & breadth of cotyledons.

The relative width of the cotyledon was also determined (breadth / length x 100), and the related standard errors (SE) and coefficient of variation (CV%) were computed. 50 seeds were sown in the field for future research, in addition to those placed in iron trays. Seeds were sowed in rows 25-30 cm apart. The spacing between two rows was approximately 30 cm. The field was watered on a regular basis, and it was constantly monitored. No chemicals or fertilizer were utilized. Seedswere sowed in second week of September in 2022–23. In mature plants, the following morphological traits were studied:

3.2.1.3 MEAN NUMBER OF LEAVES

To score this characteristic, the total number of radical leaves in 25 plants from each variety and their intervarietal hybrids was counted right before the flowering stem formed.

3.2.1.4 MEAN NUMBER OF LEAF LOBES

To determine this, the total number of leaf lobes in 10 radical leaves from each of 25 plants in each variety and their intervarietal hybrids was counted shortly before bolting.

3.2.1.5 MEAN NUMBER OFBRANCHES

Thenumber of secondary branches emerging from the primary axis was counted in 25 plants of each variety and hybrid, when the plants reached full maturity, and the mean was calculated.

3.2.1.6 PLANT HEIGHT

To assess this trait, the heights of 25 plants from each variety and intervarietal hybrids were measured shortly before harvesting.

3.2.1.7 DAYS TO FLOWER

The date of the first flower's blooming was documented for this purpose. Its difference from date ofsowing determined number ofdays till first blossoming.

3.2.1.8 NUMBER OFSTOMATA /UNIT AREA

The number ofstomata detected in one microscopic field was recorded. 25 such unit areas from each variety and hybrid were considered, and the mean was rated.

3.2.1.9 NUMBER OF CHLOROPLAST / GUARD CELL

To score this criterion, the totalnumber of chloroplasts present ineach guard cell wascounted from 50 cells of each variety and intervarietal hybrids. The substance was treated with Iodine.

3.2.1.10 MEAN NUMBER OF OVULES / PISTIL

Ten flower buds ranging in size from 10 to 12 mm were selected from 20 plants of different kinds and hybrids at the same time and preserved in 70% alcohol. Pistils were meticulously dissected with a needle under the dissecting microscope, and the number of ovules present was counted. Thus, 100 pistils from each variety and hybrid were analyzed to determine the average number of ovules.

3.2.3 PHYSIOLOGICAL STUDIES

3.2.3.1 RATE OF TRANSPIRATION

A rocket plant twig is taken. Ganong's Potometer is used for the experiment. After filling the plant chamber with water, a plant twig is put into the chamber using a rubber stopper. The free bent end of the horizontal tube is put below the water level in a beaker whose water has been colored reddish by adding a few drops of safranin. An extra amount of water is taken in the reservoir at the start of the experiment. One air bubble is put into the horizontal tube. The water in the horizontal tube is regulated as desired using the stop cork, which is located just below the water reservoir. Vaseline is used to make the equipment airtight.

Here, the distance covered by the air bubble in the horizontal tube owing to suction pressure is monitored minutely.

3.3 HYBRIDIZATION EXPERIMENT

To generate F1 hybrids between different variations, 25 to 30 mature buds ranging in sizefrom 8 to 10mm were delicately emasculated from each of 25 plants of a variety using a pair of tiny forceps while avoiding disrupting or hurting other floral elements. Old flowers and little flower buds have been removed. Emasculated flower buds were packaged in paper and tightly tied to the support, with some absorbent cotton placed on the peduncle.

All information, including the date of emasculation, the quantity of emasculated flower buds, and the name of the variety, was labeled. A separate record was also kept. Pollen grain preparations for crossing were done on the emasculation date. Anthers were extracted from a large number of flower buds that were just about to open and stored in clean, sterilized petridishes. The next day, flowers were pollinated by brushing the intended male parent's pollen onto their stigma. After pollination, flower buds were bagged and tided in the same manner.

TABLE 3.1 CROSSES BY CODE

FEMALE PLANT	MALE PLANT
GNT	LCT
GNT	LVG
LCT	GNT
LCT	LVG
LVG	LCT
LVG	GNT

Using rectified spirit, all tools and hands should be sanitized during the experiment. The F2 seeds were obtained by selfing F1 plants.

3.4 CYTOLOGICAL STUDIES

Following cytological characteristics were studied

3.4.1 MEAN NUMBER OF CHROMOCENTERS

Mature flower buds ranging in sizefrom 8 to 10 mmwere fixed in acetic alcohol (1:3) to score this criterion. A few drops of 2 percent Fecl3 solution were added to fixative as a mordant. Flower buds were dissected, & just stigmatic region was dyed & crushed with 2 percent acetocarmine. Scoringwas performed in two stigma receptive cells per plant, and a total of ten plantsfrom each vatiety and F1 hybrid were investigated. Chromocenter counts were performed exclusively on properly squashed cells.

3.4.2 POLLEN VIABILITY

Mature flower buds from 25 plants of each type and their F1 hybrids were harvested concurrently to determine pollen viability. Approximately 100 pollen grains from each type and hybrid were analyzed to determine the proportion of viable pollens.

The method of Johen Ferreira (1985) was employed. In fact, Hacker (1963) and Nortan (1966) changed their approach for Brassica pollen. MTT[3 - (4, 5 - dimethylthiazolyl -2, 5- diphenyl tetrazoliumbromide] was combined with 5 parts of a 60% sucrose solution. A drop is applied to pollen put on a microscope slide. Viable pollens react with MTT to generate a pink hue. This procedure employed only freshly gathered pollen grains.

3.4.3 MEAN NUMBEROF SEEDS / SILIQUE

To investigate mean number ofseeds per silique in open pollination, 10 siliques from each of the 20 plants of each variety were plucked and meticulously dissected with a sharp blade and needles to count number of seeds, and the mean was calculated. All of these data were statistically analyzed. The standarderror (SE) & coefficient ofvariation (CV%) were determined. The significance of differences between various kinds and their hybrids was assessed using student's t-test.All cytological data were analyzed statistically using t-tests.

CHAPTER 4

OBSERVATION AND RESULT DISCUSSION

4.1 INTRODUCTION

Although the physical properties of these three Indian rocket variants are known to some extent and briefly discussed in the preceding chapter, they have not been extensively explored. As aresult, one of current investigation's goals wasto characterize these varieties based on morpho-phisiological characteristics such as seed germination, seedling morphology, habit, leaf morphology, number ofchloroplasts per guardcell, number ofstomata per unit area, rate of transpiration, numberof branches, plant height, and number ofdays required for flowering. Studies of these characteristics for two consecutive years have clearly demonstrated the presence of adequate morphological variability in them.

.

4.2 MORPHOLOGICAL PARAMETERS

4.2.1 PERCENT SEED GERMINATION

In every genetic study, seed weight and germination are considered crucial characteristics. These are quantifiable characteristics. These features are extensively researched in a variety of cultivated plants to determine genetic variability and heritability.

As previously stated, germination tests were conducted under similar environmental circumstances. It was pretty fascinating to see that all the three kinds did not resemble one other in terms of % seed germination and differed greatly from one another. The observed intervarietal variations in percentage seed germination are probably linked to genotypic characteristics.

TABLE 4.1: % OF SEED GERMINATION OF SAMPLE

MATERIALS	YEAR	BASED ON 100 SEEDS IN EACH FORM		
		MEAN	± S.E.	CV%
GNT	2022	80.3	± .42	1.64
	2023	81.1	± .26	1.01
LCT	2022	80.3	± .27	1.14
	2023	81.4	± .26	1.01

LVG	2022	78.8	± .36	1.51
	2023	79.8	± .26	1.07

The mean difference between all the types is significant at the 1% or 5% level.

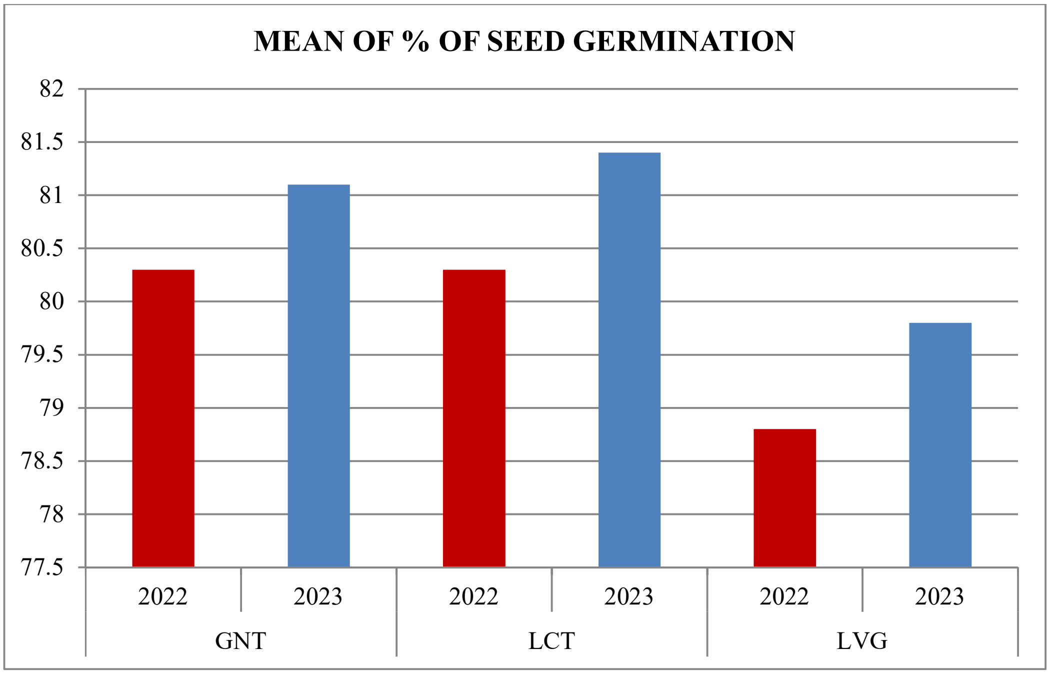
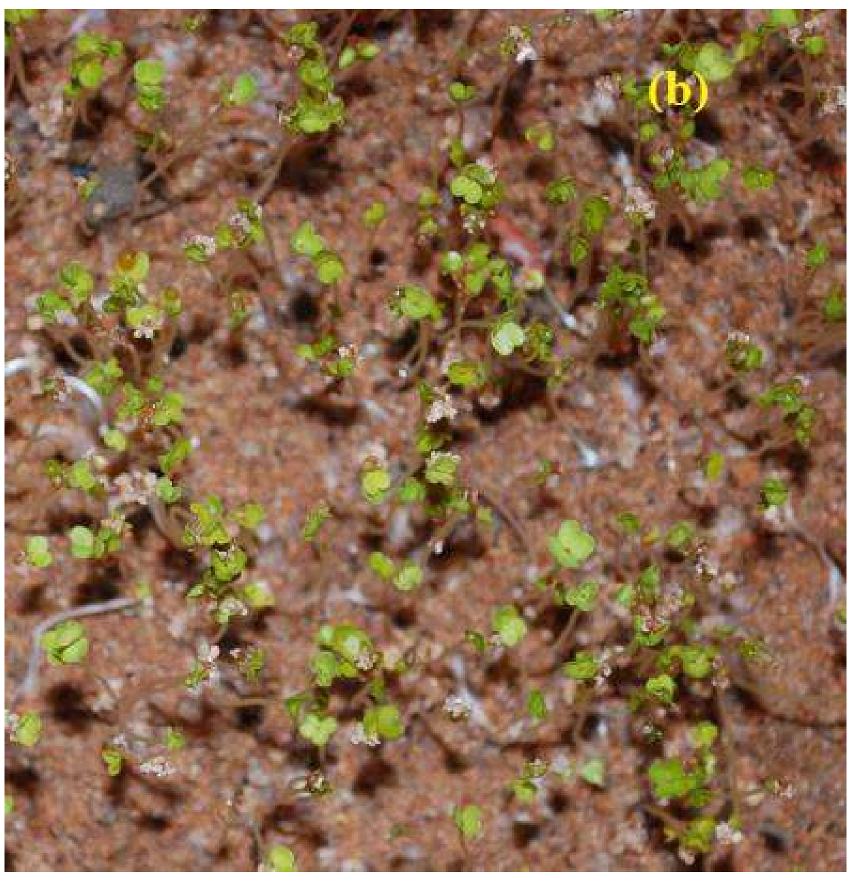


FIGURE 4.1 MEAN OF % OF SEED GERMINATION OF SAMPLE

4.2.2 SEEDLING MORPHOLOGY

Seedlings are young plants that have grown from a seed. It possesses specific morphological traits. The study of seedling morphology is extremely important in both systematic and applied genetics and plant breeding. An attempt was made to analyze two seedling characteristics, namely hypocotyl length and cotyledon area, in the three kinds of Indian rocket. (See figure 4.2)


(a)


(b)

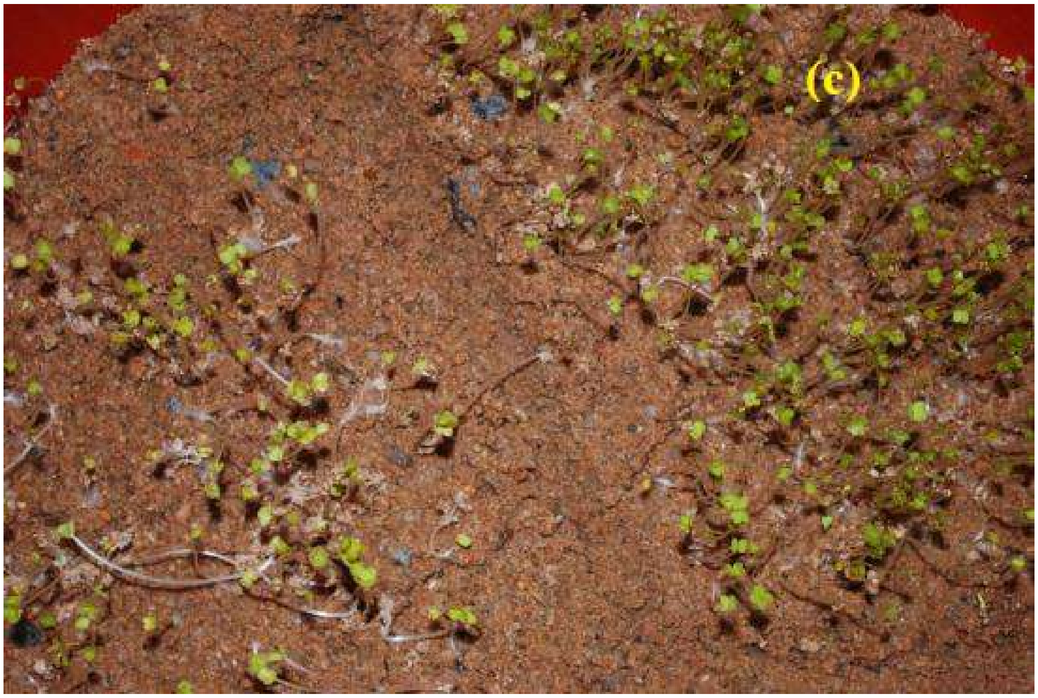


FIGURE 4.2: SEEDLING OF SAMPLE AND % SEED GERMINATION

4.2.2.1 HYPOCOTYL LENGTH

Hypocotyl length was measured in 100 seedlings from each variety, and the findings are shown in Table 4.2 & Figure 4.3. The data plainly showsthat most of the types vary considerably in mean hypocotyl length.

This measure also shows significant differences across various types. LVG had the shortest hypocotyl, with a mean length of around 4 & 6 mm in both years of research. LCT and GNT possessed the biggest hypocotyls, measuring 6 and 7 mm in length, respectively.

These types also differed in the co-efficient of variation. GNT and LCT have the largest co-efficients of variation (Table 4.2), whereas LVG has the lowest.

TABLE 4.2 SEEDLING MORPHOLOGY IN SAMPLE (HYPOCOTYL)

MATERIALS	YEAR	HYPOCOTYL LENGTH (mm)*a		
		MEAN	± S.E.	C.V. (%)

GNT	2022	5.5	± .15	9.10
GNT	2023	6.2	± .16	9.18
LCT	2022	5.6	± .16	10.17
LCT	2023	6.4	± .15	7.61
LVG	2022	5.5	± .16	2.96
LVG	2023	6.1	± .21	11
*Based on 100 seedlings in each form. a. Mean difference of all the varieties GNT, LCT and LVG is significant at 1% or 5% level.				

FIGURE 4.3: DIFFERENT SELECTED ERUCA PLANT

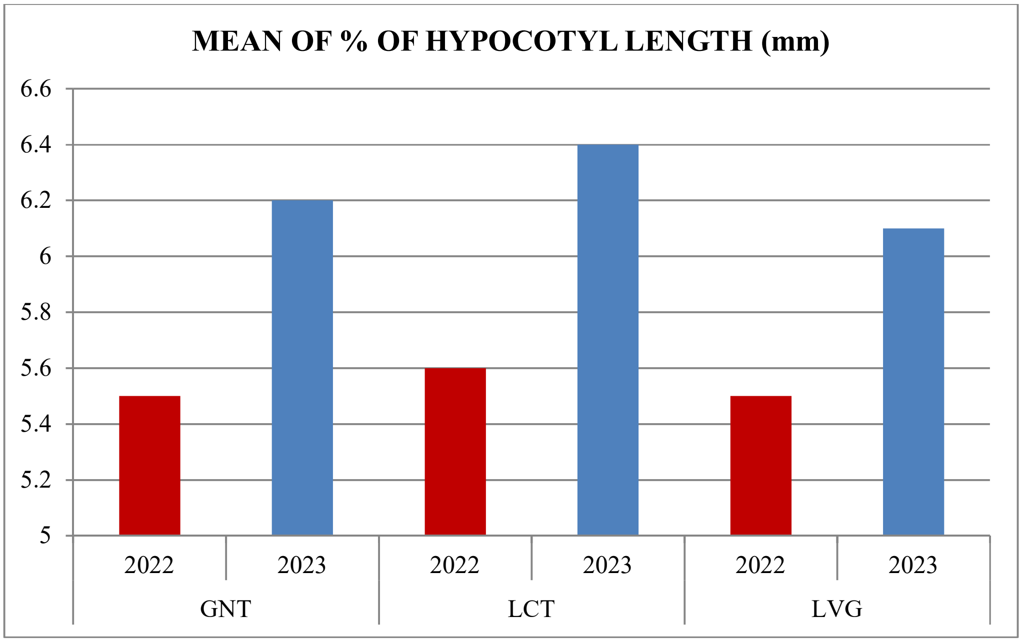


FIGURE 4.4: MEAN HYPOCOTYL LENGTH IN DIFFERENT VARIETIES OF ERUCA PLANT

4.2.2.2 MEAN COTYLEDON AREA

To determine the mean cotyledon area, the length and breadth of the cotyledons in 100 mature seedlings were measured with a divider and scale, then multiplied. The relative length of the cotyledon lamina, or the width-to-length ratio (B/L%), was also investigated. (Table 4.3)

It was discovered that in all variations, the cotyledon breadth was always bigger than the length. LCT had the largest cotyledon, measuring 5 mm, followed by GNT, which had a breadth of 4 mm. LVG has somewhat narrower cotyledons than LCT and GNT, measuring 3 mm. As a result, we can notice a 1mm disparity between various types in this metric.

In terms of cotyledon length, LCT and GNT had the longest, measuring 5 and 4 mm, respectively. LVG exhibited the smallest cotyledon length.

TABLE 4.3 SEEDLING MORPHOLOGY IN SAMPLE (COTYLEDON)

MATERIALS	YEAR	MEAN COTYLEDON AREA *[a](mm^2)					
		LENGTH			BREADTH		
		MEAN	± S.E	CV(%)	MEAN	± S.E	C.V.(%)

GNT	2022	4.8	± .24	14.88	8.5	± .15	5.94
GNT	2023	5.6	± .16	14.32	8.4	± .22	8.06
LCT	2022	5.2	± .24	14.32	8.5	± .16	6.28
LCT	2023	5.8	± .24	12.36	9.3	± .18	6.85
LVG	2022	3.7	± .14	11.06	7.5	± .15	6.72
LVG	2023	4.4	± .22	11.07	8.4	± .16	5.77

*Based on 100 seedlings in each form.

a. Mean difference of all the varieties GNT, LCT and LVG is significant at 1% or 5% level.

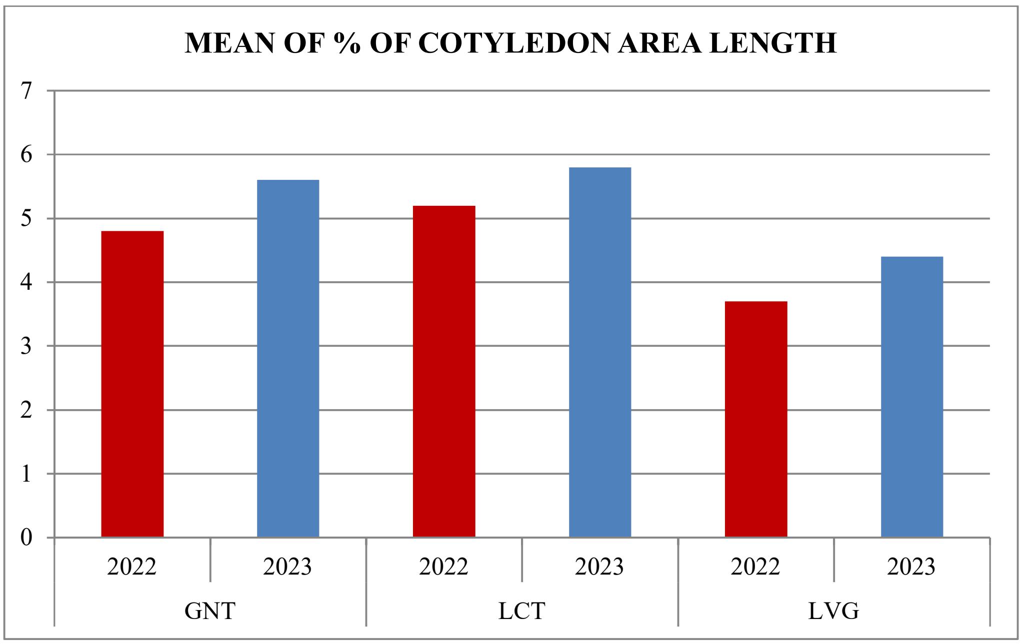


FIGURE 4.5: MEAN COTYLEDON AREA (LENGTH) IN DIFFERENT VARIETIES OF ERUCA PLANT

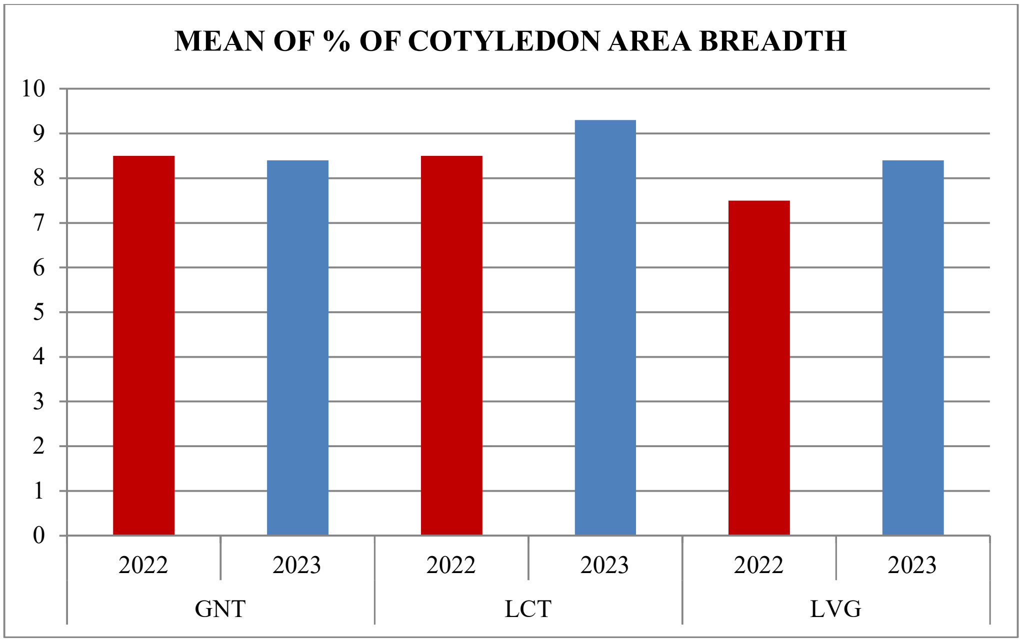


FIGURE 4.6: MEAN COTYLEDON AREA (BREADTH) IN DIFFERENT VARIETIES OF ERUCA PLANT

Although some morphological characteristics of these Indian varieties of Rocket are known and briefly discussed in the previous chapter, some morphological features such as leaf morphology, number of per plant, plant height, & total number of days to appearance of the first flower have not been studied. An comprehensive investigation of these factors over two years revealed significant morphological changes in these types, which may have significant implications in systematic and plant breeding. Aside from it, general features of the plant habit have been noticed.

4.2.3 LEAF MORPHOLOGY

Rocket has pinnateleaves that are strongly lobed, withfour to ten little lateral lobes & one huge terminal lobe. It would not be incorrect to have a brief glance at the general habit of plants that looked to be comparable in practically all of these kinds before learning about the leaf morphology. The usual habit. All three plant kinds exhibit pinnatifid segmentation. LVG leaves are smaller than the other two types, GNT and LCT.

4.2.4 NUMBER OFLEAVES PERPLANT

The average numberof leaves per plant was examined. The total numberof radical leaves from each of 25 plants in each variety were counted immediately before the flowering stalk emerged. It was investigated for two consecutive years. The findings are shown in Table 4.4 & Figure 4.7. The table shows that average number of leaves per plant varies significantly across the three kinds. These differences have also been demonstrated in terms of co-efficient of variation. (CV%) GNT had the highest mean number of leaves in two consecutive years (56 & 62), followed by LCT (59 & 60). LVG had the fewest number of leaves, with 40 and 39 in two consecutive years.

TABLE 4.4: MEAN NUMBER OF LEAVES

MATERIALS	YEAR	BASED ON 25 PLANTS IN EACH FORM		
		MEAN	± S.E.	C.V. (%)
GNT	2022	12.8	± .16	4.35
GNT	2023	13.7	± .26	5.77
LCT	2022	12.7	± .18	4.93
LCT	2023	13.5	± .15	3.76
LVG	2022	9.5	± .15	5.43
LVG	2023	10.5	± .35	11.04
a. Mean difference of GNT is significant from, LCT and LVG that of LCT from LVG and LVG is significant at 1% level.				


(a) GNT


(b) LCT

FIGURE 4.7: NUMBER OF LEAVES OF VARIETY GNT, LCT AND LVG RESPECTIVELY

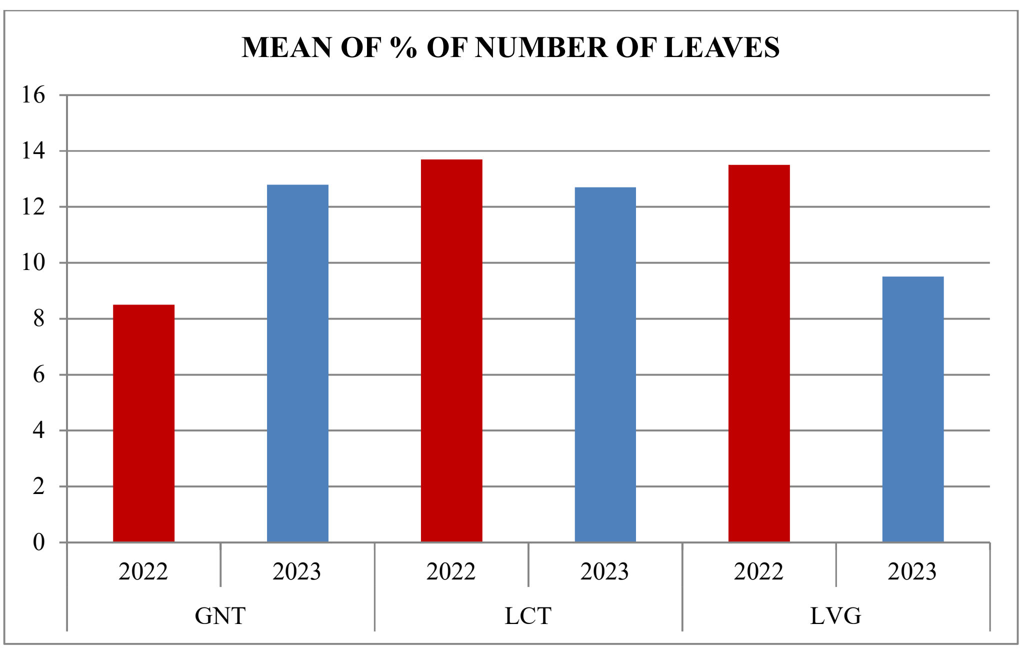


FIGURE 4.8: MEAN NUMBER OF LEAVES PER PLANT IN DIFFERENT VARIETIES OF SAMPLE

4.2.5 NUMBER OF LEAF LOBES

For this purpose, the number of lobes in ten leaves from each of 25 plants in each variety was measured immediately before bolting for two years in a row. The findings are shown in table 4.5 & figure 4.9. Thenumber of leaf lobes varied significantly across all kinds. The greatest number of leaf lobes in GNT is 12, followed by 11 in LCT and 9 in LVG

TABLE 4.5: MEAN NUMBER OF LEAF LOBES

MATERIALS	YEAR	BASED ON 25 PLANTS IN EACH FORM		
		MEAN	± S.E.	C.V. (%)
GNT	2022	11.2	± .26	7.84
GNT	2023	12.2	± .24	6.04
LCT	2022	11.5	± .24	6.14
LCT	2023	12.4	± .26	6.76
LVG	2022	10.1	± .21	2.26
LVG	2023	10.5	± .15	4.96

a. Mean difference of GNT from all LVG from all except LCT is significant at 1% or 5% level.

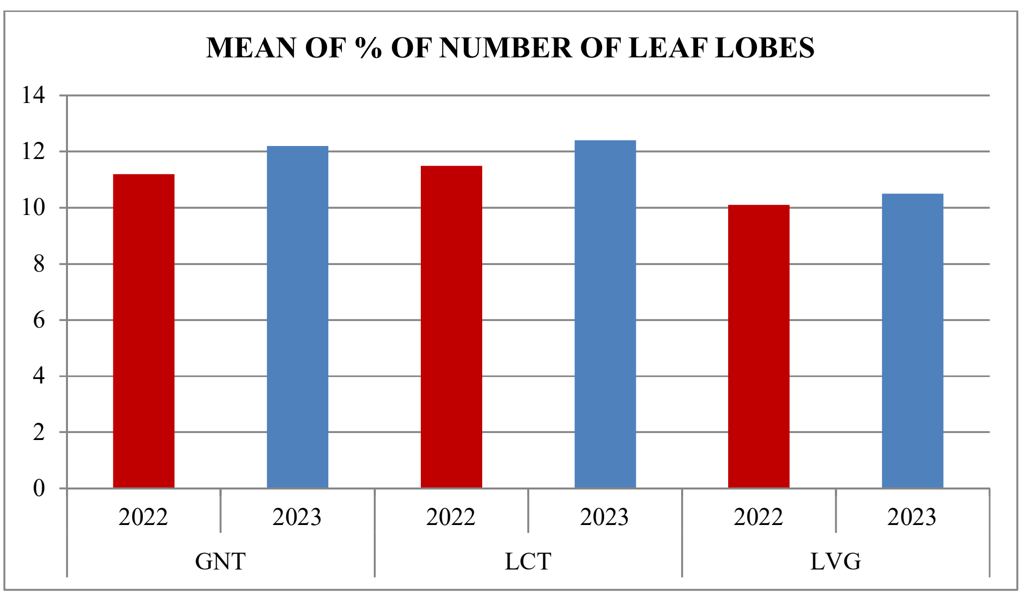


FIGURE 4.9: MEAN NUMBER OF LEAF LOBES PER PLANT IN DIFFERENT SAMPLE

4.2.6 NUMBER OF BRANCHES

Another morphological trait that was investigated was the average number of branches per plant. Before harvesting, 25 plants from each type had their secondary branches growing from the main axis counted. The mean number of branches varies significantly across the three kinds, as illustrated clearly in table 4.6 and figure4.10.

TABLE 4.6: MEAN NUMBEROF BRANCHES PER PLANT

MATERIALS	YEAR	BASED ON 25 PLANTS IN EACH FORM		
		MEAN	± S.E.	C.V. (%)
GNT	2022	10.8	± .26	7.97
GNT	2023	12.2	± .24	6.04
LCT	2022	11.4	± .22	5.93
LCT	2023	12.2	± .24	6.04
LVG	2022	9.8	± .24	7.36
LVG	2023	10.6	± .28	8.77
a. Mean difference of GNT from all, LCT from all except LVG is significant at 1% or 5% level.				

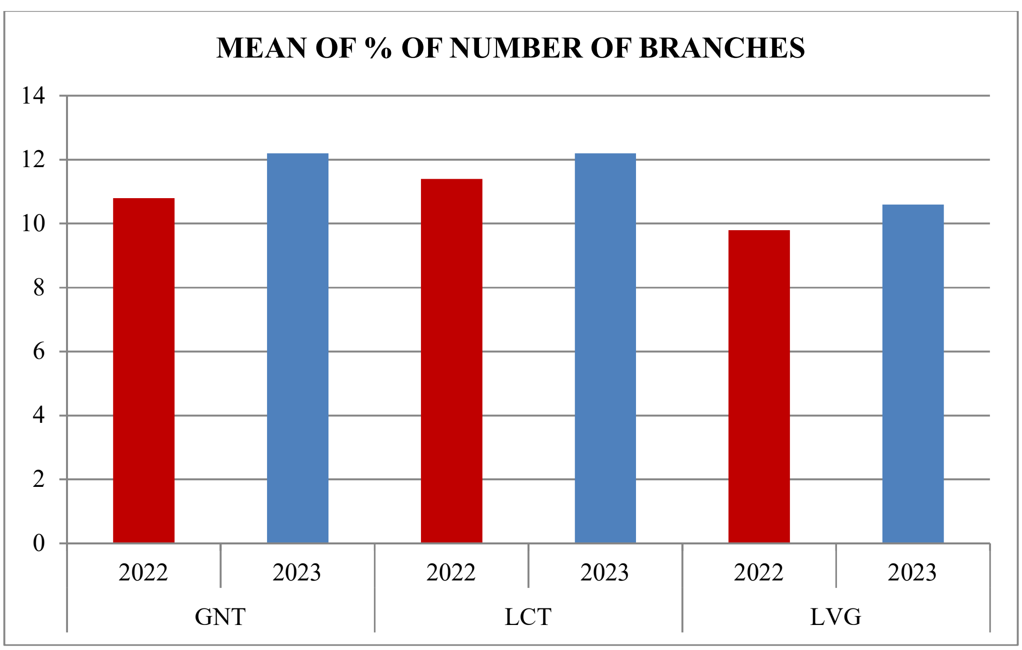


FIGURE 4.10: MEAN NUMBER OFBRANCHES PER PLANT IN DIFFERENT SAMPLE

4.2.7 PLANT HEIGHT

Another morphological trait that was investigated was plant height. For this, height of plant was measuredusing a scale and thread in 25 plants from each type right before harvesting for two consecutive years. The findings areshown in Table 4.7 & Figure 4.11. The table shows that most of the types vary considerably in this dimension. Plants within the variety also showed minor variance. LVG had a minimum height of roughly 53 cm in both years of research, followed by LCT at 59 cm and GNT at 62 cm. These variances have also been seen in terms of CV%.

TABLE 4.7: MEAN OF PLANT HEIGHT

MATERIALS	YEAR	BASED ON 25 PLANTS IN EACH FORM		
		MEAN	± S.E.	C.V. (%)
GNT	2022	66.85	± 2.88	15.06
GNT	2023	74.53	± 4.43	18.81
LCT	2022	69.43	± 3.15	14.34
LCT	2023	79.06	± 4.95	20.41
LVG	2022	65.42	± 3.15	15.17
LVG	2023	75.38	± 3.21	15.06

a. Mean difference of GNT is significant from LCT and LVG that of LCT from LVG is significant at 1% or 5% level.

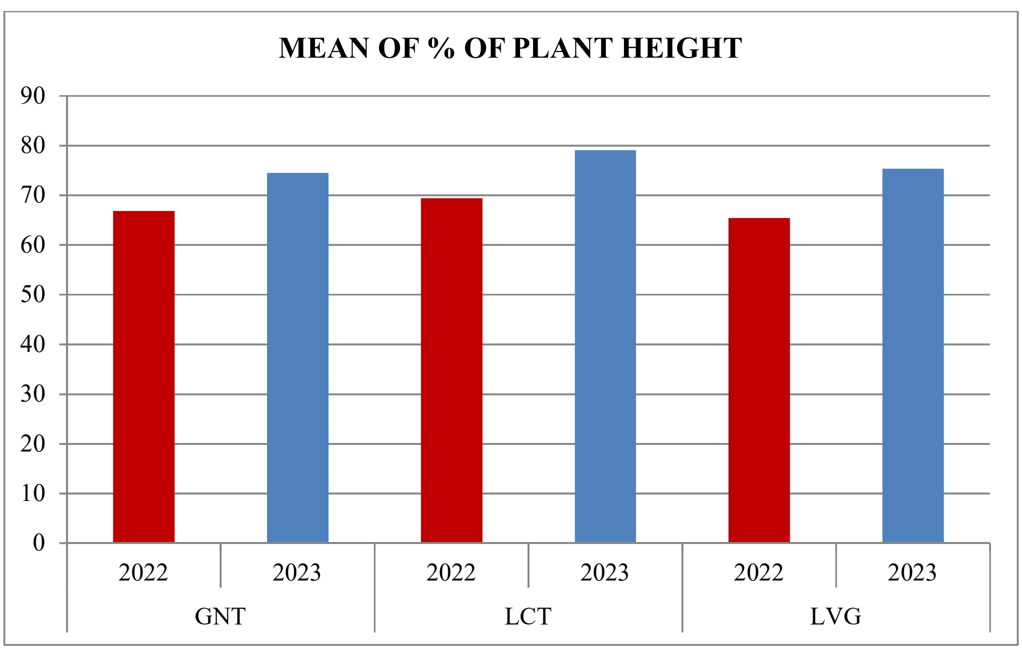


FIGURE 4.11: MEAN OF PLANT HEIGHT OF SAMPLE

4.2.8 DAYS TO FLOWER

The amount of days it takes for the first blossom to develop varies significantly across the three types of Rocket. LCT required the most number of blooming days (49), followed by GNT (46), and LVG (36).

A short examination of the plants revealed that the variety LVG produced the most blooms, whereas the variety LCT produced the fewest. LVG was known for having the smallest blooms. Other variants produced both medium-sized flower buds and flowers. The blooms in all three kinds were yellow.

TABLE 4.8: MEAN OF DAYS TO FLOWER

MATERIALS	YEAR	BASED ON 25 PLANTS IN EACH FORM		
		MEAN	± S.E.	C.V. (%)
GNT	2022	41.2	± .22	1.46
GNT	2023	37.4	± .15	1.18
LCT	2022	43.7	± .51	3.66
LCT	2023	40.6	± .35	2.65
LVG	2022	34.8	± .24	2.08
LVG	2023	33.6	± .28	2.77

a. Mean difference of GNT from all, except LCT is significant at 1% or 5% level.

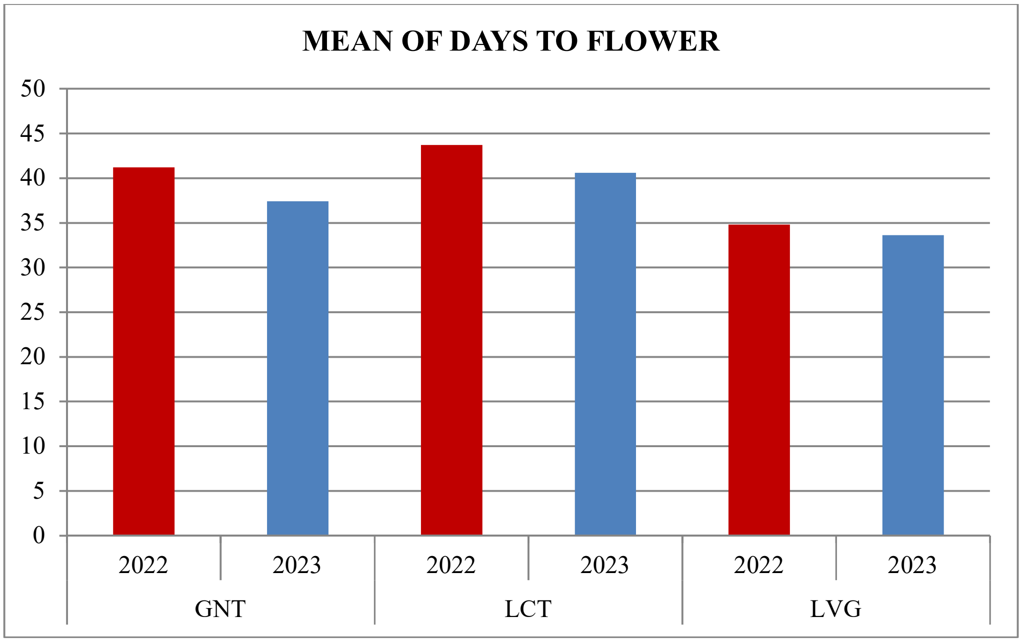


FIGURE 4.12: MEAN OF PLANT HEIGHT OF SAMPLE

4.3 STOMATAL CHARACTERS

Anatomical features give evidence for the connection of bigger groupings such as families and aid in determining the affinities of genera with ambiguous taxonomic statuses. Taxonomic importance is associated with anatomical traits based on histology of stomatal distribution and structure. Stomata, which are also part of the epidermal tissue system, have been studied, which is quite valuable in taxonomy. Aside than being a member of the Brassica case family. Rocket is distinguished by the presence of cruciferous type stomata. This kind surrounds the guard calls with three unequal subsidiary cells. In this study, only two stomatal features were considered: Average number ofstomata per unit area & chloroplasts per guard cell.

4.3.1 MEAN NUMBER OFSTOMATA PER UNITAREA

To investigate mean number ofstomata per unit area, total numberof stomata observed in each of twenty-five unit areas under the compound microscope (H. P.) was counted independently in each variety and statistically evaluated. The mean was calculated. The findings are shown in Table 4.9.

The Table shows that all three kinds displayed sufficient variance in this parameter. LVG had the largest meannumber of stomata per unitarea in both years of investigation, about 9.65, and varied considerably from all other kinds. The variety LCT ranked second on the list in this metric, with a mean of roughly 4.35 and a substantial difference from the other variations. GNT had lowest mean numberof stomata perunit area across both years of investigation and varied considerably from the other kinds.

TABLE 4.9: MEAN NUMBER OFSTOMATA PER UNITAREA

MATERIALS	YEAR	BASED ON 25 PLANTS IN EACH FORM		
		MEAN	± S.E.	C.V. (%)
GNT	2022	8.5	± .43	15.57
GNT	2023	9.7	± .25	7.96
LCT	2022	9.6	± .46	15.06
LCT	2023	11.4	± .35	10.16
LVG	2022	9.6	± .66	21.67
LVG	2023	12.1	± .45	11.76
Mean difference of GNT is significant from LCT and LVG that of LCT from LVG and LVG is significant at 1% or 5% level.				

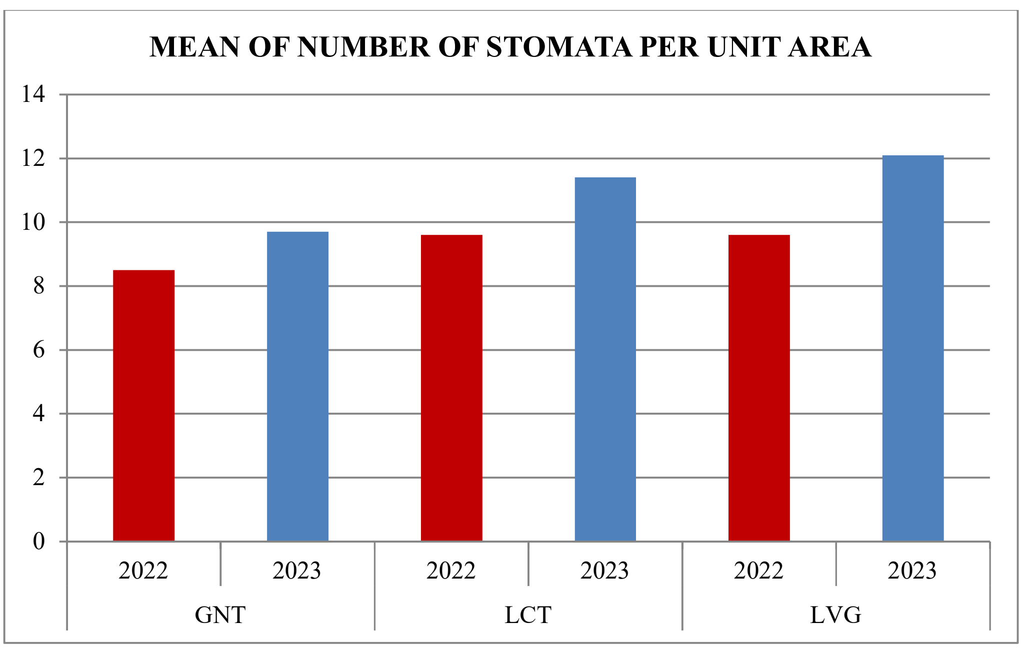


FIGURE 4.13: MEAN OF NUMBER OF STOMATA PER UNITAREA

4.3.2 NUMBER OF CHLOROPLAST PER GUARD CELL

All green parts of a plant have chloroplast. These are the larger cell organelles found in a plant cell embedded in the cytoplasm. In present investigation, only mean numberof chloroplast per guardcell was scored. Number ofchloroplasts per guard cell differs from species to species in angiosperms & may play important role in determining taxonomic status of a particular group of plant. In order to score this parameter, total number of chloroplasts present in each of 100 guard cells of stomata were counted in each variety and mean was scored. The results are presented in Table 4.10 & Fig. 4.14. From the Table it may be noted that these varieties demonstrated variation among themselves in the meannumber of chloroplast per guard cell. Plants within variety also demonstrated some variations. LCT the highest mean number of chloroplast present in each of the 100 guard cells of the stomata were counted in each variety and mean was scored.

From the Table it may be noted that these varieties demonstrated variation among themselves in the meannumber of chloroplast per guardcell. Plants within variety also demonstrated some variation. LCT the highest mean numberof chloroplasts perguard cell i.e. 12.6 in both the years of study and differed significantly from all other varieties. GNT, L.V.I demonstrated the lowest mean number of chloroplast perguardcell around 11.37 & 8.06 respectively.

TABLE 4.10 MEAN NUMBER OF CHLOROPLASTPER GUARDCELL

MATERIALS	YEAR	BASED ON 25 PLANTS IN EACH FORM		
		MEAN	± S.E.	C.V. (%)
GNT	2022	6.5	± .25	12.73
GNT	2023	9.2	± .32	10.81
LCT	2022	6.6	± .34	15.66
LCT	2023	8.1	± .26	10.13
LVG	2022	7.7	± .18	8.06
LVG	2023	1.5	± .48	14.82
Mean difference of GNT from all, LCT from all and LVG from all is significant at 1% level.				

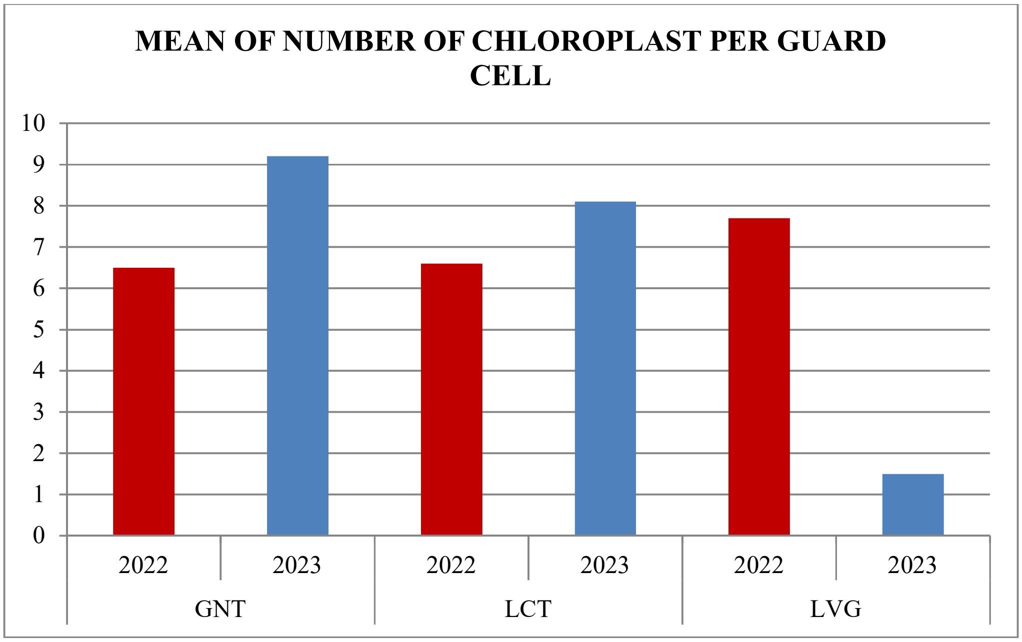


FIGURE 4.14: MEAN OF NUMBER OF STOMATA PER UNIT AREA

4.4 FERTILITY CHARACTERS

Fertility is a complexcharacter. It depends on anumber of biological processes right from the development of the reproductive organs to fertilization and the embryogeny. It involves the development of ovules in the ovary and pollen grains in the anthers, pollination and fertilization which ultimately lead to the formation of seeds and the fruits. Mean number of ovules in ovary & the mean numberof seeds in the silique are important parameter that may indicate genotypic variability within the varietal populations of a cross-pollinating crop like Rocket.

4.4.1 MEAN NUMBER OF OVULES

In order to study mean number of ovules in the ovary, Flower buds of size 8 to 10 mm, which were yet to open, were simultaneously collected and fixed in 70% alcohol till the final investigation. Pistils were dissected out carefully with the help of needles under the dissecting microscope. 10 flower buds from each of the 20 plants of a variety were dissected for counting of ovules. Thus, altogether 200 pistils were scored for the mean number of ovules in each variety.

Mean number of ovules in the ovary appeared to be a very conservativ character. It was quite constant in both the years of study and was characteristic of a particular variety.

Almost all the three varieties differed significantly among themselves in this parameter (Table 4.11 Fig. 4.15). LCT had the highest number of ovules per ovary in both the years of study and differed significantly from all other varieties. It has around 33.3 ovules per ovary while LYG had the lowest with a mean around 19.65 The no. of ovules /pistil in GNT has taken intermediate position i.e. 24.94. (table 4.11 & figure 4.15)

TABLE 4.11: MEAN NUMBER OF OVULES

MATERIALS	YEAR	BASED ON 20 PLANTS IN EACH FORM		
		MEAN	± S.E.	C.V. (%)
GNT	2022	31.1	± 1.58	16.23
GNT	2023	36.7	± 1.01	8.65
LCT	2022	31.5	± 1.65	16.63
LCT	2023	36.5	± 1.02	8.93
LVG	2022	25.7	± .98	12.21
LVG	2023	29.8	± .55	5.76
Mean difference of GNT from all, LCT from all and LVG from all is significant at 1% level.				

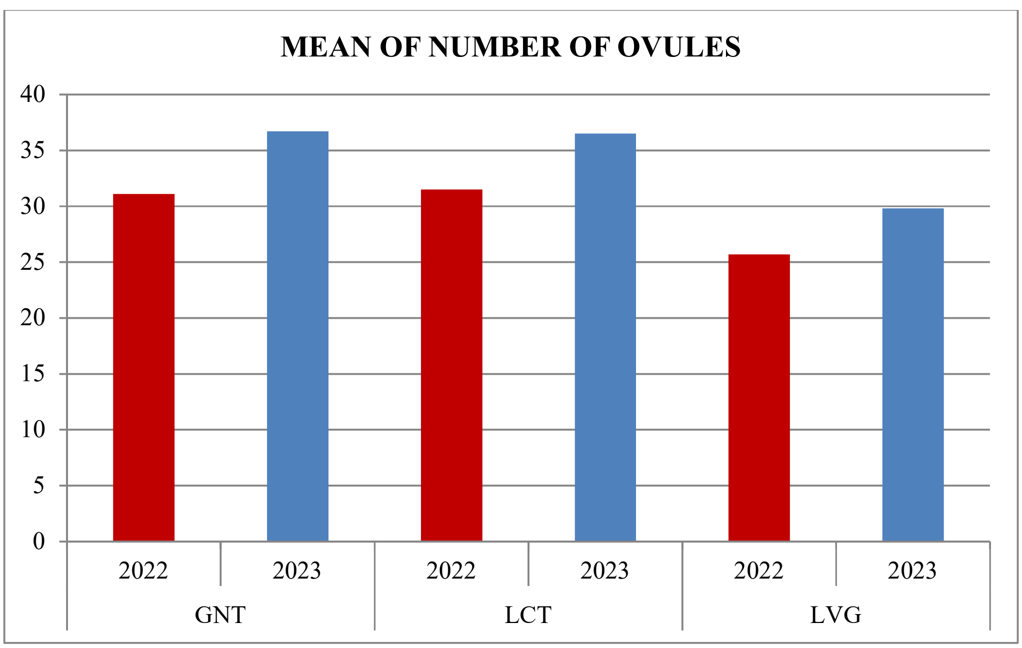


FIGURE 4.15: MEAN OF NUMBER OF OVULES

These varieties also varied in the co-efficient of variations the highest percentage of co-efficient of variation being 39.64 in LCT while about 28.53 LVG in showing the lowest percentage of CV. As a whole, the number of ovules in the ovary ranged from 8 to 11.

4.4.2 MEAN NUMBER OFSEEDS PERSILIQUE

Fertility in terms of seed set under open pollination was studied and results are presented in a tabular form Table 4.12, Fig. 4.16). Inorder to study mean number of seedsper silique in open pollination, 10 silique from each of the 20 plants of each variety were harvested and dissected carefully with the help of a fine blade and needle to count the number of seeds , & mean number of seedsper silique was scored which was found constant in both the years of study and was characteristic of a particular variety.

Except all three varieties differed among themselves in this parameter. LCT has highest number of seeds per silique about 23.4 while LVG exhibited lowest number of seeds per silique around 19.65, GNT showed intermediate almost the same value 24.93 in this trait. These varieties also showed remarkable difference in the percent of co-efficient of variations. LCT demonstrated the highest percentage in both the years of study. Followed by GNT & LVG.

TABLE 4.12: MEAN NUMBER OF SEEDS/SILIQUE

MATERIALS	YEAR	BASED ON 20 PLANTS IN EACH FORM		
		MEAN	± S.E.	C.V. (%)
GNT	2022	26.1	± 1.28	14.05
GNT	2023	33.8	± 1.08	9.54
LCT	2022	30.7	± 1.28	14.05
LCT	2023	35.5	± 1.13	10.01
LVG	2022	21.3	± .97	12.26
LVG	2023	27.7	± .51	5.52
Mean difference of all the varieties is significant from each other at 5% level.				

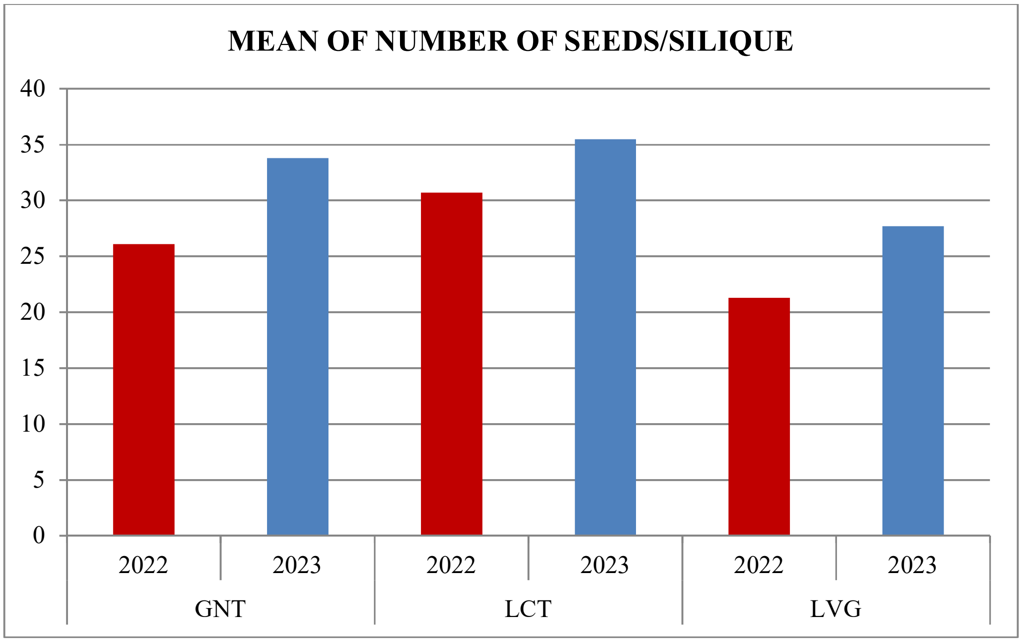


FIGURE 4.16: MEAN OF NUMBER OF SEEDS SILIQUE

4.4.3 FERTILISATION VALUE (FV)

It has already been mentioned earlier that fertility is a complex character and dependson a number offactors. Such as number and quality of male and female reproductive organ and the processes leading to fertilization and embryogeny. It also depends onenvironmental conditions. To understand characteristics of seed formation in different varieties of Rocket the fertilization value was calculated and studied. With help ofthis parameter it is possible to evaluate number of functional ovules which are capable of formingseeds. In open pollination, all the three varieties differed significantly from each other in fertilization value. The fertilization value in LCT was the highest 29.74% 2. Followed by GNT (Table 13 Fig. 4.17). It was the lowest in LVG

TABLE 4.13: MEAN OF FERTILIZATION VALUE

MATERIALS	YEAR	BASED ON 20 PLANTS IN EACH FORM		
		MEAN	± S.E.	C.V. (%)
GNT	2022	29.71	± 1.25	14.02
GNT	2023	28.84	± 2.46	8.13
LCT	2022	24.84	± .67	12.01
LCT	2023	23.88	± 1.46	10.01

LVG	2022	22.97	± .92	17.11
LVG	2023	23.66	± .96	18.01
Mean difference of all the varieties is significant from each other at 1% and 5% level.				

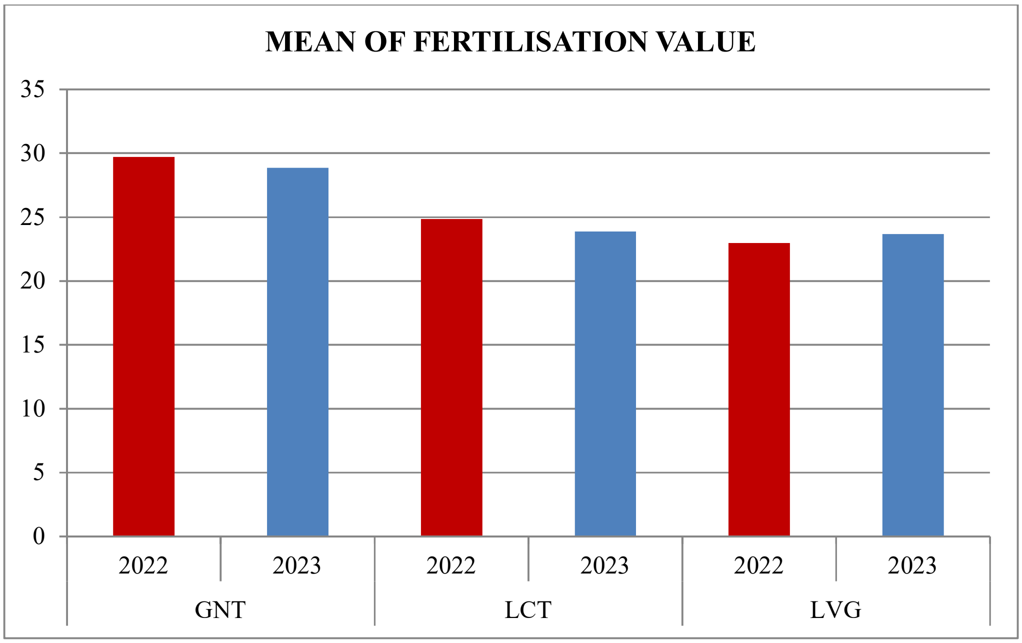


FIGURE 4.17: MEAN OF FERTILISATION VALUE

4.5 RATE OF TRANSPIRATION

Rate of transpiration was measured in three varieties of Rocket with the help of Ganong's potometer. Materials used in the measurement of rate of transpiration was beaker, Ganong's potometer, a plant twig of Rocket and safranin solution .Transpiration creates suction on the water surface present in a plant chamber,What amount of water that was evaporated during this process through the ariel parts of the plant twig, can be measured with the help of graduated horizontal tube on the potometer. To measure the rate of transpiration the plant chamber is filled with water and the twig of rocket was inserted to the chamber by means of a rubber cork.The free bend end of the horizontal tube is placed below the water level contained in a beaker whose water is made reddish by adding a few drops of safranin. One air bubble is introduced in the horizontal tube.The regulation of water in the horizontal tube , as desired is made with the help of stop cork, present just below the water reservoir. The application of Vaseline or wax was helpful in the making of the apparatus air tight.

The distance covered by the air bubble in the horizontal tube , which is caused due to exertion of suction created by transpiration, was observed minutely. The recorded observation is shown in table 4.14 and fig.4.18

TABLE 4.14: RATE OF TRANSPIRATION

MATERIALS	YEAR	TIME TAKEN CONSTANT (30min)	BASED ON 10OBSERVATION					RATE OF TRANSPIRATION
			Distance moved	MEAN	± S.E.	RANGE	C.V. (%)	
GNT	2022	12:30 to 1:00pm	10	9.8	± .26	9-11	14.02	.33
GNT	2023	1:00 to 1:30pm	12	12.1	± .34	10-13	8.13	.40
LCT	2022	12:40 to 1:10pm	10	9.8	± ..12	9-11	12.01	.33
LCT	2023	1:10 to 1:40pm	14	11.6	± .35	11-13	10.01	.46
LVG	2022	1:00 to 1:30pm	13	77.1	± .26	10-12	17.11	.43
LVG	2023	12:30 to 1:00pm	10	12.1	± .35	11-13	18.01	.33
Mean difference of all the varieties is significant from each other at 1% level.								

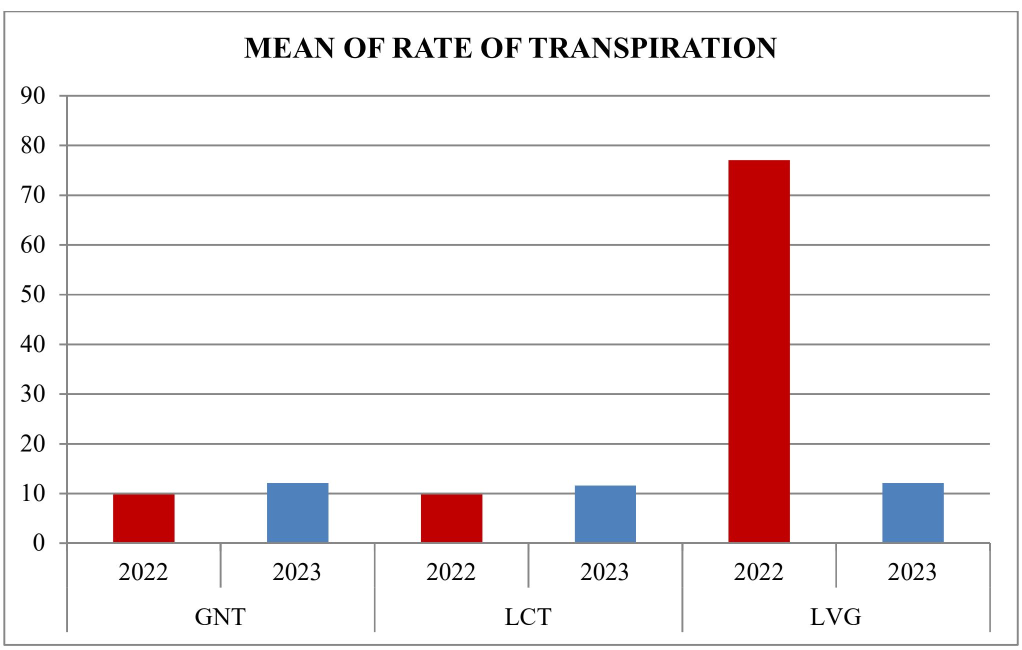


FIGURE 4.18: MEAN OF RATE OF TRANSPIRATION

4.6 INTERVARIETAL HYBRIDIZATION

In order to raise F1 hybrids between different varieties of the Indian Rocket and to understand their reproductive biology, these varieties were crossed among themselves. As they had different flowering periods and were sown simultaneously in the field, it was not possible to cross them in all directions. In most cases the variety LVG served as the female parents or as the pollinator because these flowered earlier and flowering lasted for a longer period.

The hybridizations results have been presented in Table 4.15. From the table it is clear that LCT crossed well with GNT and gave 82.53% silique set. The mean number ofseed set in the silique was 32.73. Crosses of LCT and LVG also gave high percentage of silique set 87.91.

Mean number ofseed set in the silique 39.05 and number of seed set in silique ranged from 1 to 18. The crosses GNT & LVG exhibited almost the same percentage of silique set, between 76.32 to 81.71%. Crosses of LVG & LCT was, however least successful exhibiting only 74.85% Silique set

TABLE 4.15: MEAN OF % OF SILIQUE SETTING

MATERIALS	NO. OF FLOWERS COSSED	BASED ON 10 PLANTS IN EACH FORM		
		MEAN	± S.E.	C.V. (%)
LCT X LVG	150	70.5	± .52	2.33
LCT X GNT	100	72.8	± .83	3.55
GNT X LCT	200	72.1	± .64	2.76
GNT X LVG	150	74.4	± .94	3.96
LVG X LCT	250	70.5	± .66	2.93
LVG X GNT	250	72.7	± .86	3.54
Mean difference of all the varieties is significant from each other at 1% level.				

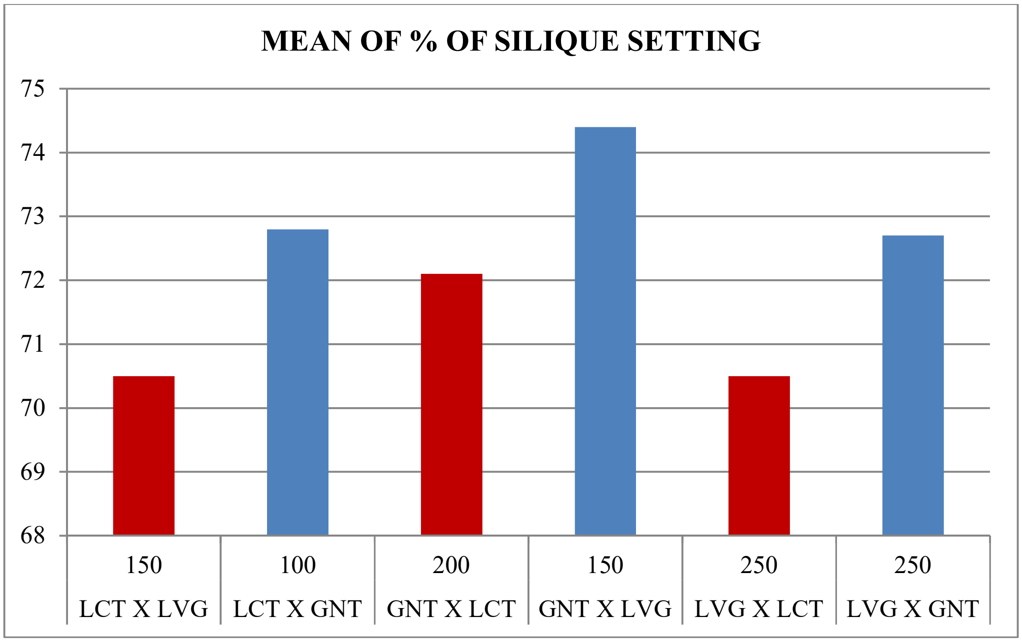


FIGURE 4.19: MEAN OF % OF SILIQUE SETTING

TABEL 4.16: MEAN OF NUMBER OF SEEDS / SILIQUE SET

MATERIALS	**NO. OF FLOWERS COSSED**	**BASED ON 10 PLANTS IN EACH FORM**			
		MEAN	± S.E.	C.V. (%)	RANGE
LCT X LVG	150	36.6	± .46	3.92	35-39
LCT X GNT	100	37.7	± .33	2.73	36-39
GNT X LCT	200	36.7	± .47	3.98	35-39
GNT X LVG	150	39.8	± .64	5.05	37-42
LVG X LCT	250	24.7	± .83	10.53	22-28
LVG X GNT	250	28.2	± .8.5	9.54	266

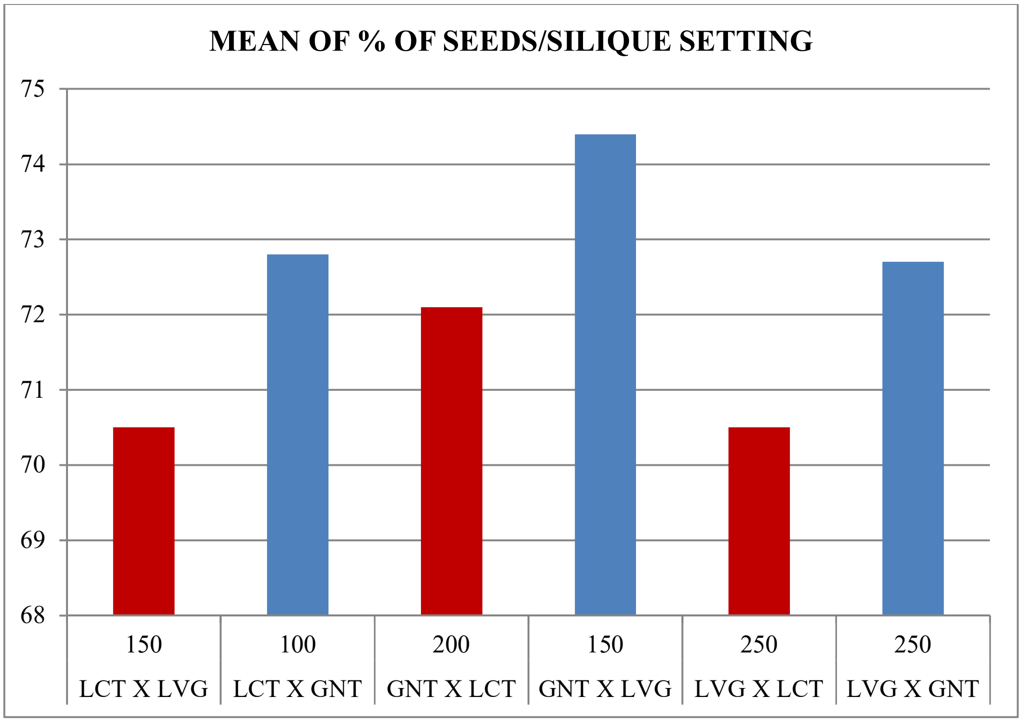


FIGURE 4.20: MEAN OF NUMBER OF SEEDS/SILIQUE SET

4.7 COMPARATIVE MORPHOPHISIOLOGICAL STUDIES OF DIFFERENT VARIETIES OF ROCKET AND THEIR F1 HYBRIDS

4.7.1 PERCENT SEED GERMINATION

All three cultivars display exceptional stability in terms of % seed germination. As a consequence, a comparative analysis of % seed germination in various types and F1 hybrids was performed, and the findings are shown in Table 4.17 Fig 4.21. Germination studies were done under identical environmental conditions. Only 200 seeds from each F1 hybrid were seeded to measure seed germination percentage. The hybrid LCT X GNT had the greatest percentage of seed germination of all the hybrids, 91.64%, followed by LVG X GNT, 90.68%. The hybrid GNT X LCT had the lowest percentage of seed germination (84.42%). The Table shows that all of their F1 intervariatal hybrids, with the exception of LCT X LV.I. and LCT X GNT, had considerably higher mean values than their parental forms. This may be considered an instance of heterosis. GNT × LCT and GNT X L.V.I exhibited similar parental seed germination to GNT and LCT, respectively. These cultivars and their F1 hybrids clearly differed in terms of seed germination percentages.

The discrepancies in % seed germination between F1 hybrids may be related to their genotypic characteristics.

TABLE 4.17: COMPARATIVE ANALYSIS OF % SEED GERMINATION IN VARIOUS TYPES AND F1 HYBRIDS

NAME OF THE VARIETIES AND HYBRIDS	SEED GERMINATION(%)*a		
	MEAN	± S.E.	CV%
LCT	81.3	± 0.25	1.00
LCT X LVG	86.4	± 0.47	1.73
LCT X GNT	85.4	± .61	2.28
GNT	81.1	± .25	1.00
GNT X LCT	85.1	± .48	1.78
GNT X LCT	85.9	± .54	1.49
LVG	79.9	± .27	1.08
LVG X LCT	86.9	± .31	1.13
LVG X GNT	84.8	± .73	2.75

*Based on 100 seeds in each hybrid and variety.

*a. The mean difference in percent seed germination across all hybrids is significant at the 5% level.

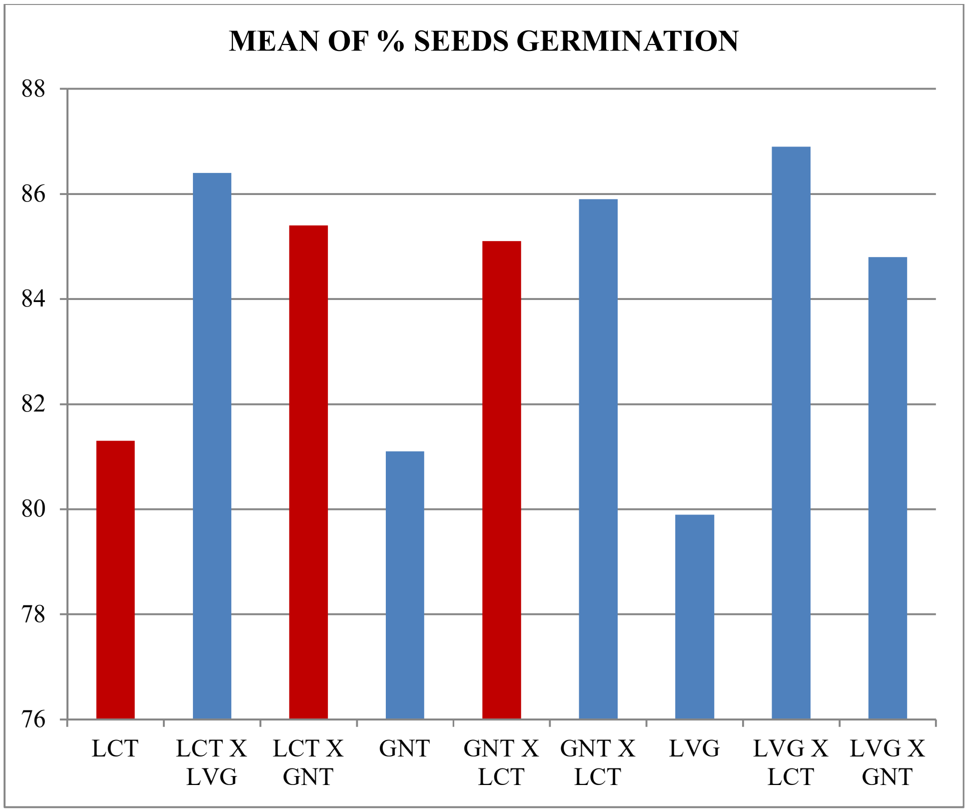


FIGURE 4.21: % SEED GERMINATION IN F1 INTERVARIETAL HYBRIDS AND THEIR PARENTS

4.7.2 SEEDLING MORPHOLOGY IN F1 HYBRIDS

Seedling morphology is an important topic in both systematic and applied genetics and plant breeding research. The seedling characteristics of the three different types of Rocket are quite distinct and may be used effectively in genetic studies. As a result, an attempt was undertaken to analyze primarily two seedling characteristics, hypocotyl length and length, and cotyledon area, in distinct types of the Indian rocket and their three hybrids.

4.7.2.1 MEAN HYPOCOTYL LENGTH

To investigate hypocotyl morphology, 100 seedlings from each F1 hybrid and their parental forms were measured in length. It is clear that these types and their F1 hybrids vary considerably in mean hypocotyl length (Table 4.18.Fig. 4.22). Plants within the types and F1 hybrids also showed significant diversity. It has previously been stated that all three kinds showed exceptional uniformity in mean hypocotyl length. It was fascinating to see that in all three F1 intervariatal hybrids, the mean hypocotyl length was intermediate, falling somewhere between the mean hypocotyl lengths of their parental forms. The mean hypocotyl length in LCT × LVG was similar to LCT × GNT. The table shows that intervarietal hybrids, such as LCT × L.V.I and GNT, have much longer mean hypocotyls than their parental forms, indicating heterosis. Individual plants within the hybrids also showed significant diversity. The hybrid LCT × LVG & GNT. × LCT had the longest hypocotyls, with a mean length of 8 mm. L.V.I × LCT had the smallest, measuring just 5 mm. LCT × GNT ranked second in this metric, with a mean hypocotyl length of 7 mm.

The F1 hybrids also differed significantly in terms of co-efficient of variation. Some F1 hybrids, such as LCT × L.V.I, GNT × LCT, and GNT × LVG, showed higher percent co-efficients of variation than their parental forms. Others had an intermediate value, meaning it fell somewhere between their parental forms.

4.7.2.2 MEAN COTYLEDON AREA

Another seedling characteristic investigated was the mean cotyledon area. For this, the length and breadth of cotyledons in 100 mature seedlings of various types and F1 hybrids were measured and multiplied. In addition, the relative breadth of the cotyledon was scored.

The breadth of the cotyledon was found to be bigger than the length in all F1s. The data shows that the F1 had substantial differences in mean cotyledon area (data 4.19, Fig. 4.23). In all six F1 intervariatal hybrids, the mean cotyledon area was intermediate, falling between the mean cotyledon areas of their parental forms. However, the hybrid LVI & LCT had a considerably greater mean cotyledon area than the parental forms, indicating heterosis. The mean cotyledon area of LCT × GNT was closer to LCT, whereas GNT × L.V.I was closer to GNT. In L.V.I × GNT closer to LVG The hybrid LCT X LVG had the highest mean cotyledon area, followed by LCT × GNT. The hybrid L.V.I × GNT had the lowest mean cotyledon area (Table 9, Fig. 16).

Intervarietal F1 hybrids (LCT × LVI, LCT × GNT, and GNT X L.V.I) outperformed their parental forms in cotyledon mean length.

TABLE 4.18 SEEDLING MORPHOLOGY IN DIFFERENT VARIETIES OF ROCKET AND THEIR F1 HYBRIDS

MATERIALS	HYPOCOTYL LENGTH(mm)*a			COTYLEDON AREA*b					
				LENGTH			BREADTH		
	MEAN	S.E.	CV%	MEAN	S.E.	CV%	MEAN	SE	CV%
LCT	6.3	±.16	7.61	5.9	±.23	12.37	9.2	±.19	6.84
LCT X LVG	6.8	±.28	13.38	5	±.20	13.2	10	±.33	10.5
LCT X GNT	6.3	± .21	10.63	4.2	±.24	18.57	9.3	±.25	8.81
GNT	6.1	±.17	9.18	5.7	±.15	14.31	8.3	±.21	8.07
GNT X LCT	6.9	±.17	8.11	4.8	±.19	14.65	9.8	±.24	7.95
GNT X LVG	7.5	±.16	6.93	5.6	±.26	15	10.6	±.30	9.05
LVG	6	±.20	11	4.3	±.21	11.08	8.3	±.15	5.78
LVG X LCT	4.6	± .21	15	4.8	±.24	16.25	9.7	±.21	6.90
LVG X GNT	5.4	±.21	12.77	5.5	±.16	9.45	10.7	±.33	9.81

*Based on 100 seedlings in each form.

*a. The mean difference between the hybrids is significant at the 1% or 5% level. The mean difference between all hybrids and their parents is significant at the 5% level.

*b. The mean difference between all hybrids is statisticallysignificant at 1% or 5% level. The mean difference b/w all hybrids and their parents is considerable.

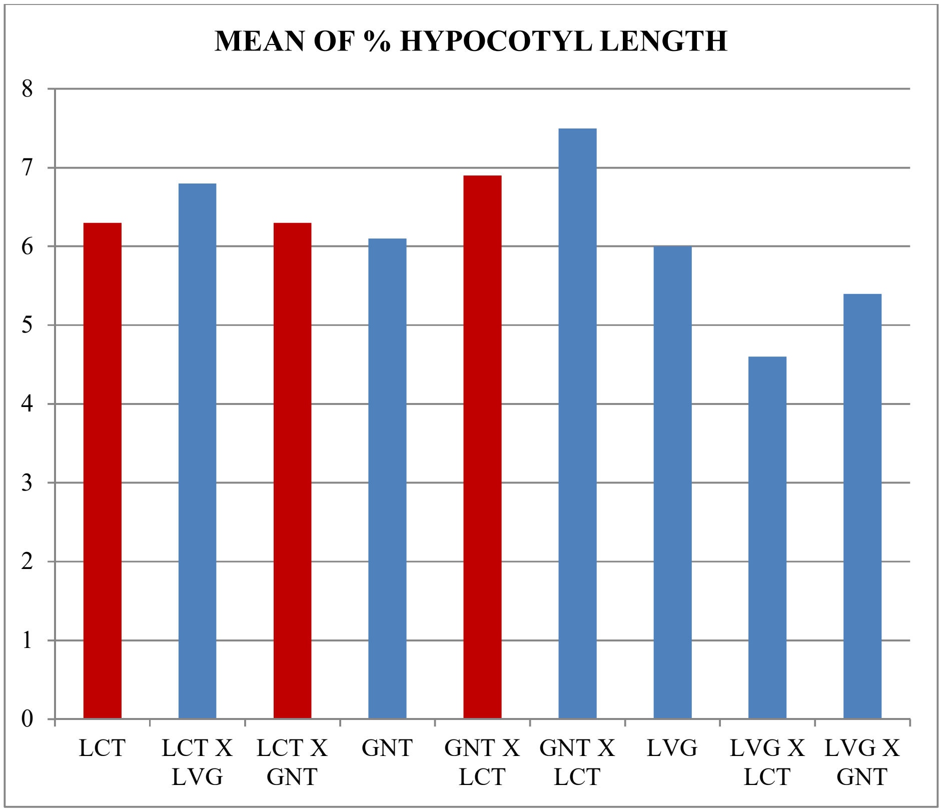


FIGURE 4.22 MEAN OF HYPOCOTYL LENGTH

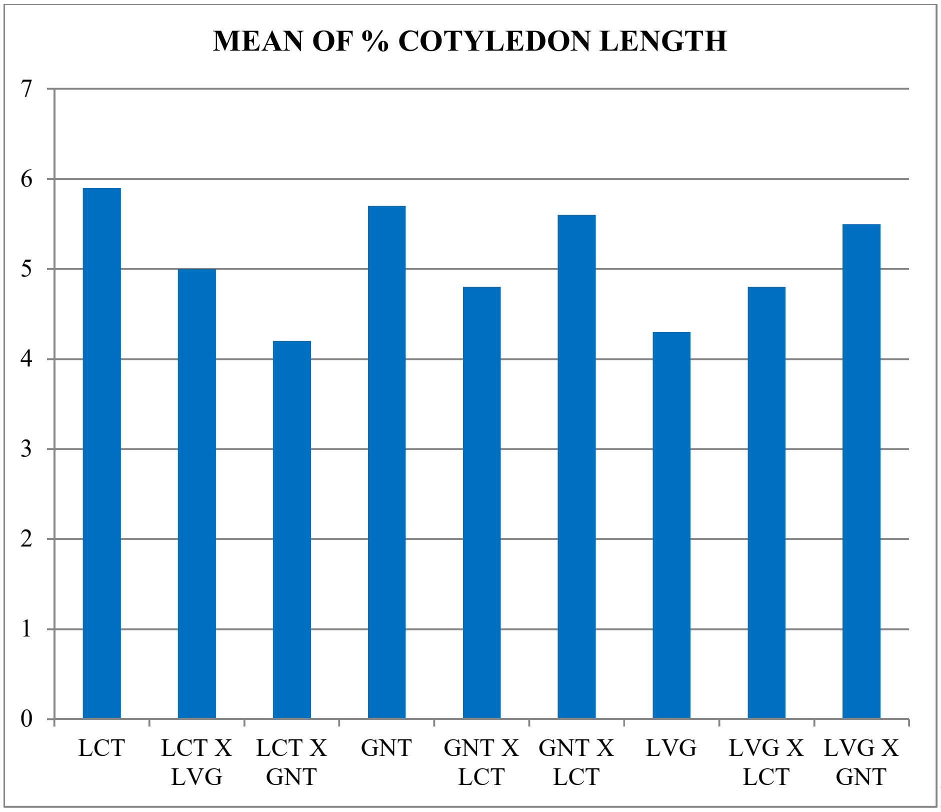


FIGURE 4.23: MEAN COTYLYDON LENGTH

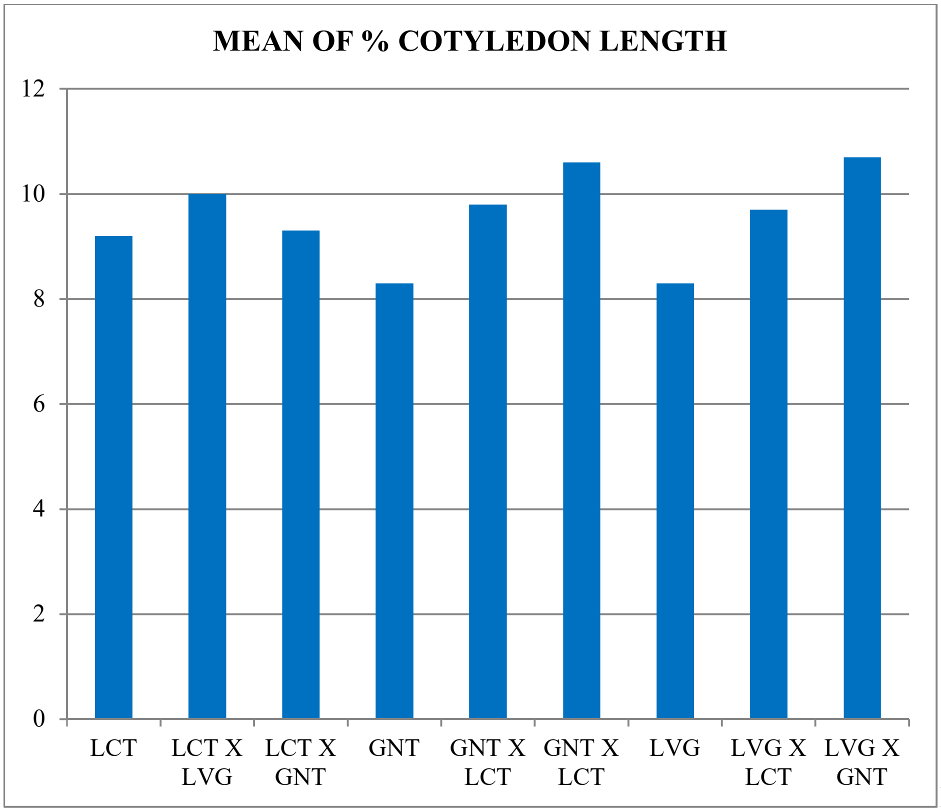


FIGURE 4.24: MEAN COTYLYDON BREADTH

Certain morphological traits may be very important in both systematic and applied genetics in plant breeding. As a result, three important morphological characters were investigated in the varieties and their F1 hybrids: leaf morphology, specifically number of leaves per plant, number of leaf lobes, number of branches per plant, plant height, & total number of days until the appearance of the first flower. A comparative description of the above-mentioned morphological trait is offered.

4.7.3 LEAF MORPHOLOGY

Rocket has pinnateleaves that are strongly lobed, with four toten little lateral lobes & one huge terminallobe. It is not incorrect to take a brief look at the overall habit of plants, which appears to be identical in virtually all types, before learning about leaf morphology.

4.7.3.1 NUMBER OF LEAVES PERPLANT.

To determine the numberof leaves per plant, total number ofleaves from each of 25 plants in each variety and hybrid was counted right before the flowering stalk emerged. In terms of the quantity of leaves per plant, all kinds vary greatly. It is worth noting that the plants within the hybrids exhibited considerable variance. The hybrid GNT X LCT had the largest mean number of leaves per plant, 20.4. It was succeeded by LCT X LVG and GNT X LVG. These variances have also been shown in terms of co-efficient of variation (cv%).

4.7.3.2 MEAN NUMBER OF LEAF LOBES

For this, lobes of 10 leaves from 25 plants of each type and hybrid were counted right before bolting. All of these cultivars have a remarkable uniformity in the average number of leaf lobes. However, intervarietal hybrids exhibited a higher mean than their parent types. The hybrid LCT X LVG produced the greatest mean, followed by LCT X GNT x GNT X LVG

TABLE 4.19 MEAN NUMBER OF LEAVES AND LEAF LOBES

MATERIALS	NUMBER OF LEAVES *a MEAN = S.E C.V %RANGE			NUMBER OF LEAF LOBES *b MEAN = S.E C.V%RANGE		
LCT	14.0=0.25	5.78	(11-13)	21.1 =0.23	6.03	(10-12)
LCT X LVG	14.8 =0.19	4.25	(14-16)	11.9 =0.23	6.13	(11-13)
LCT X GNT	15.5 =0.196	3.35	(14-16)	12.4 =0.16	4.11	(11-13)
GNT	14.0 =0.25	5,78	(12-14)	12.1 =0.23	6.03	(10-12)
GNT X LCT	14.3 =0.15	3.35	(13-15)	11.8 =0.19	5.33	(11-13)
GNT X LVG	13.5 =0.22	5.18	(13-15)	12.8 =0.21	5.56	(11-13)
LVG	10.6 = 0.36	11.03	(8-10)	10.6 = 0.16	4.81	(9-11)
LVG X LCT	11.3 =0.21	5.92	(10-120	10.5 =0.16	4.95B	(10-12)
LVG X GNT	10.5 =0.22	6.66	(10-12)	10.9 =0.17	5.13	(10-12)

Based on a study of 25 plants in each form,

*a. The mean difference between the hybrids LCT X LVG, LCT X GNT, GNT X LCT, GNT X LVG, LVG X LCT, and LVG X GNT is significant at the 1% or 5% level. The mean difference between all hybrids and their parents is significant at the 1% level.

*b The mean difference between all hybrids is statistically significant at 5% level. The mean difference b/w all hybrids and their parents is statisticallysignificant at 1 percent level.

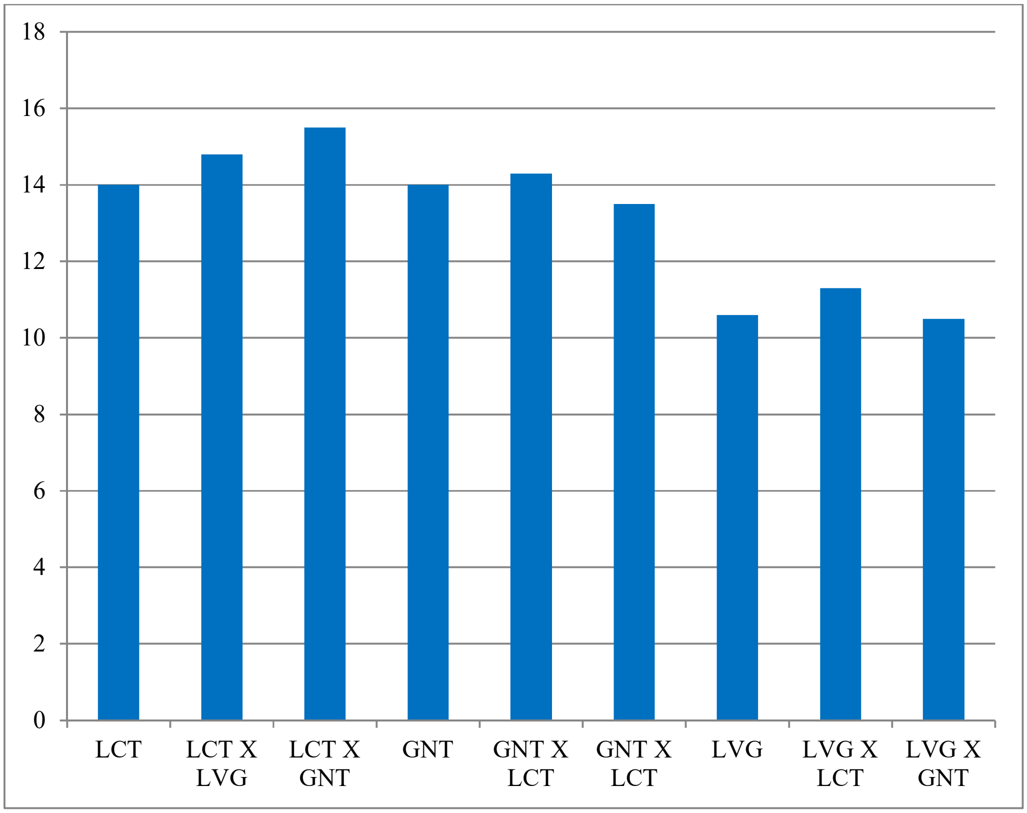


FIGURE 4.25: MEAN NUMBER OF LEAVES

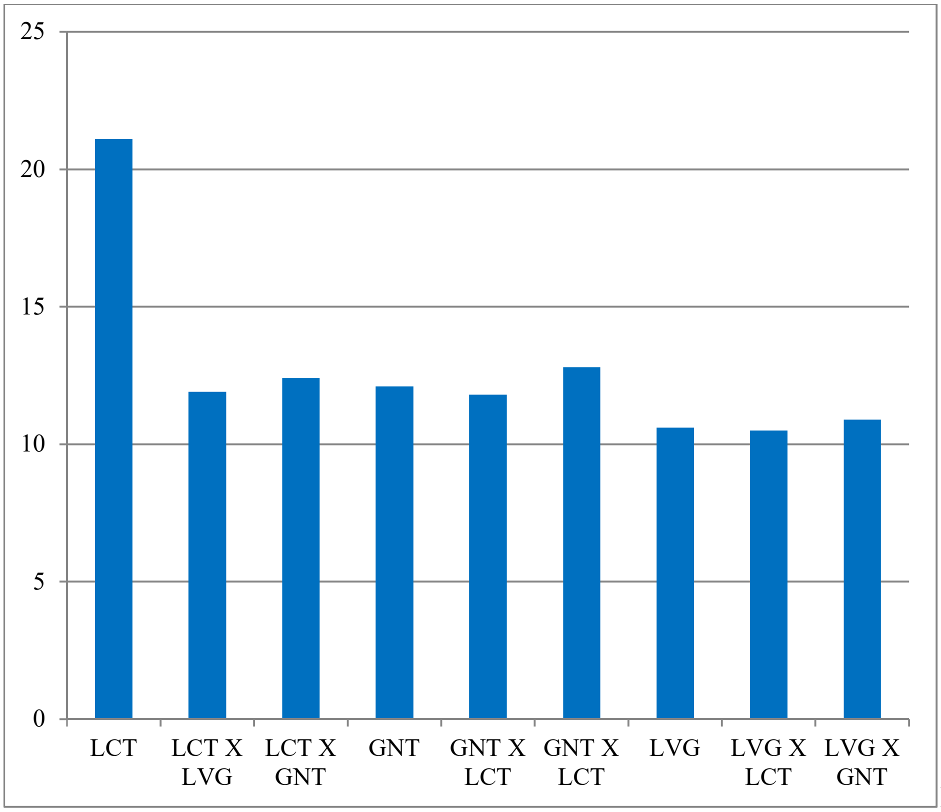


FIGURE 4.26: MEAN OF LEAF LOBES IN F1 HYBRIDS

4.7.3.3 MEAN NUMBER OFBRANCHES

Thenumber of secondary branches growing from principal axis was counted in 25 plants from each variety and their F1 hybrids (Table 4.20, Fig. 4.27). All hybrids had a larger mean number of branches per plant than their parental forms. GNT × LCT showed substantial differences from other hybrids in this metric. All of the hybrids varied greatly from their parent types. The hybrid GNT × LCT exhibited the largest meannumber of branches perplant, whereas LVG × LCT showed the lowest. The hybrids GNT X LCT, GNT × LVG, and LCT × GNT showed decreasing mean number ofbranches perplant. The individual plants in both the variety & the hybrid varied. The hybrids also differed in terms of co-efficient of variation when compared to their parental forms.

The hybrids GNT × LVG and LVG GNT have greater CV% than their parental forms. LVG × GNT showed an intermediate CV% compared to their parental forms.

4.7.3.4 PLANT HEIGHT

Another morphological trait investigated was plant height. To determine this trait, the height of 25 plants from each variety and hybrid was measured right before harvesting using a scale and thread. The findings are shown in Table 4.20. Fig. 4.28. The hybrids LVG × GNT and GNT × LCT had minimal plant heights of 19 and 21 cm. In addition, the hybrids' coefficients of variation diverged from those of their parental forms. The hybrid LCT × GNT and GNT × LVG showed greater CV than their parental forms. The hybrids LVG × GNT and LVG × LCT have decreased CV% values compared to their parental forms. This parameter varied between hybrid plants. However, the hybrids showed more variance than their original forms.

4.7.3.5 DAYS TO FLOWER

This trait differed across all three kinds and F1 hybrids. Flowering period was longer for the hybrid LVG × LCT compared to the parental forms. A LCT × L.VI., LCT × GNT, and GNT 314 × LCT all exhibited earlier blooming than their parents. A casual check at the flowers revealed that the F1 hybrids had bigger blooms than their parental forms (fig. 4.29). The hybrids LCT × GNT and GNT × LCT produced larger blooms than previous hybrids. They also have rich yellow flowers.

TABLE -4.19 MEAN NUMBER OF BRANCHES, PLANT HEIGHT, DAYS TO FLOWER

MATERIALS	MEAN NUMBER OF BRANCHES *a			PLANT HEIGHT (cm)*b			DAYS TO FLOWER*cm	
	MEAN±SE	CV%	RANGE	MEAN±	CV%	RANGE	MEAN ± SE	CV%
LCT	12.1± 0.23	6.03	(10-12)	79.05± 4.96	20.40	(57-77)	40.5± 0.34	2.66
LCTXLVG	12.4± 0.16	4.11	(12-13)	81.24± 3.33	12.98	(72-96)	45.1±0.31	2.19
LCTXGNT	13.1± 0.23	5.57	(12-14)	70.31± 4.02	18.11	(55-90)	46±0.25	1.76
GNT	12.1± 0.23	6.03	(10-12)	74.52± 4.42	18.8	(57-77)	37.3±0.16	1.19
GNTXLCT	12.2± 0.19	5.16	(11-13)	74.81± 4.57	19.35	(57-94)	44.8±0.38	2.72
GNTXLVG	12.9± 0.17	4.34	(12-14)	81.30± 3.32	13.02	(69-96)	48.7±0.25	1.87
LVG	10.7± 0.29	8.78	(9-11)	75.39± 3.20	15.05	(47-76)	33.7±0.29	2.78
LVGXLCT	11.3± 0.15	4.24	(11-12)	66.04±2.82	13.50	(54-76)	33.7±0.29	2.78
LVGXGNT	11.8± 0.19	5.33	(11-13)	76.50±3.74	15.47	(63-96)	34.4±0.37	2.79

*The study used 25 plants in each type.

a. The mean difference between hybrid LCT X GNT and all other hybrids is significant at the 1% level. The mean difference between all hybrids, with the exception of LVG X LCT and LVG X GNT, was significant at the 1% level.

b. The mean difference between all hybrids is statistically significant at 5%level. The mean difference b/w all hybrids & their parent is significant at 5% level.

*c. The mean difference between the hybrid LCT X LVG, LCT X GNT, GNT X LCT, GNT X LVG, LVG X LCT, and LVG X GNT is significant at the 1% or 5% level. The mean difference between hybrids and their parents is considerable.

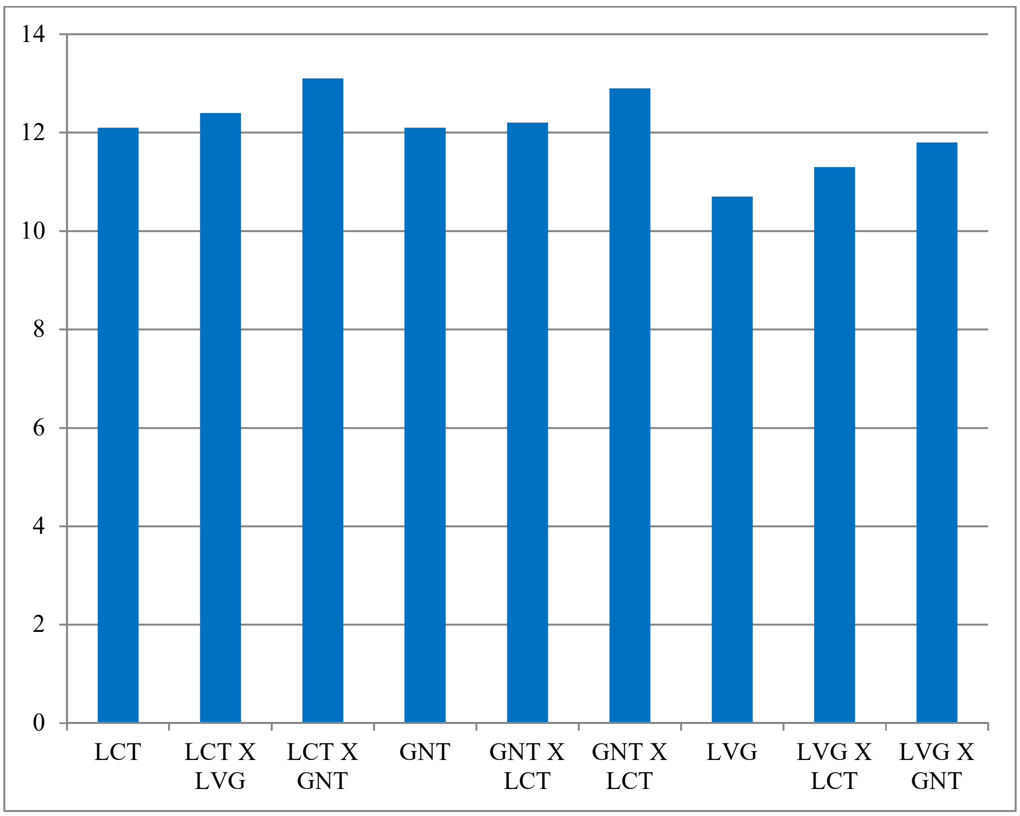


FIGURE 4.27 MEAN NUMBER OF BRANCHES

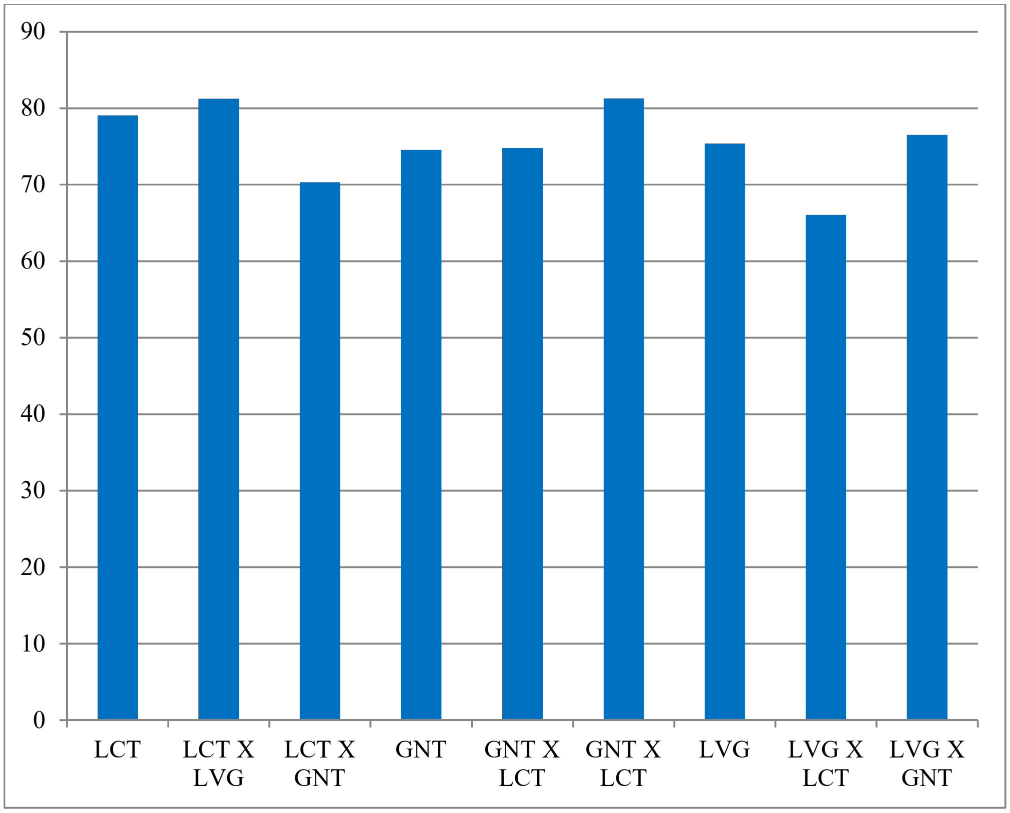


FIGURE 4.28: PLANT HEIGHT IN F1 INTERVARIETAL AND PARENTAL FORMS.

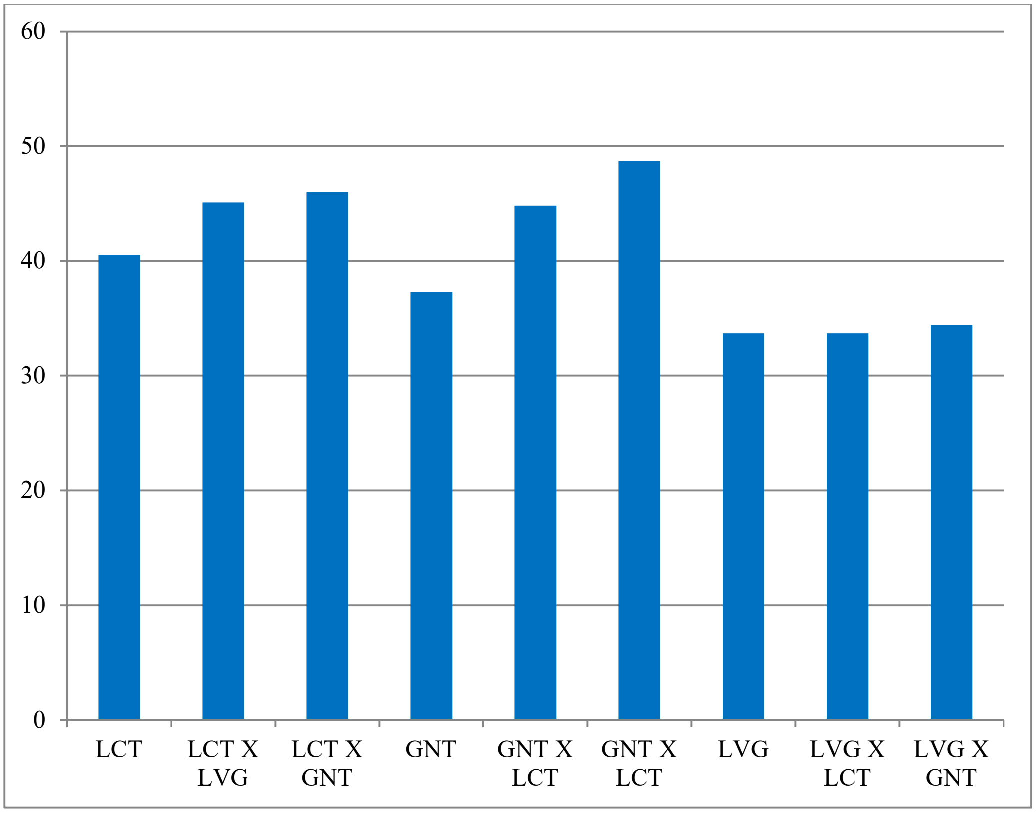


FIGURE 4.29: DAYS TO FLOWER IN F1 INTERVARIETAL AND PARENTAL FORMS.

4.7.4 NUMBER OF STOMATA PER UNIT AREA

As previously indicated, anatomical characteristics relating to stomatal structure and distribution are important for taxonomy. To determine meannumber of stomata perunit area, all stomata observed in each of the 25 unit areas under a high-power compound microscope were counted in each variety as well as six intervarietal hybrids, and the mean was calculated. The resultsare shown in Table 4.20 & Figure 4.30. The Table clearly shows that the types and their hybrids varied significantly in mean number ofstomata per unitarea. The hybrids LCT × LVG and GNT ×LVG have a higher average numberof stomata per unit areathan their parents.While in the remainder of the hybrids, it held an intermediate position, that is, between mean number ofstomata per unite area of their parental forms (Table 4.20, Fig. 4.30). The hybrid LVG ×LCT had the most stomata per unit area and stood out from other hybrids.

The F1 intervarietal hybrid also has a significant CV% variation. It was higher than their parental forms in LVG and LCT. Percentage of LCT X L.V.I and GNT × LCT. While the remainder of the hybrids were intermediate, that is, between their parental types.

4.7.5 NUMBER OFCHLOROPLASTS PER GUARDCELL

To score this criterion, total number ofchloroplasts present in 100 guard cells of stomata in each variety as well as the six intervarietal hybrids were counted, and the mean was calculated; the resultsare shown in Table 4.20, Fig. 4.31. From the table. It is clear that the varieties and hybrids showed significant variability in this characteristic. The average quantity of chloroplasts per guard cell varied greatly between types and F1 hybrids. The Table shows that all six F1 intervarietal hybrids had considerably greater means than their parental forms, which might be attributable to heterosis. The hybrid GNT × LVG had the most chloroplasts per guard cell, with an average of 13.10, whereas LVG × LCT had the fewest.

All F1 hybrids had lower co-efficients of variation than their parental forms, except for LVG × GNT, which had a higher co-efficient than either parent. The latter was also distinguished by having the largest coefficient of variation of all the hybrids. LVG × LCT had the lowest coefficient of variation.

TABLE 4.20: NUMBER OFSTOMATA PER UNITAREA, NUMBEROF CHLOROPLASTS PER GUARD CELLS IN DIFFERENT VARIETIES OF ROCKET AND THEIR F1 HYBRIDS.

MATERIALS	NUMBER OF STOMATA PER UNIT AREA*			NUMBER OF CHLOROPLAST PER GUARD CELL**		
	MEAN ±SE	CV%	RANGE	MEAN±SE	CV%	RANGE
LCT	11.3 ± 0.36	10.17	(8-11)	8 ± 0.25	10.12	(5-8)
LCTXLVG	11.6 ± 0.26	7.24	(10-13)	7.7± 0.21	8.70	(7-9)
LCTXGNT	10.6 ± 0.16	4.81	(10-11)	8.5±0.16	6.11	(5-7)
GNT	9.8 ± 0.24	7.95	(8-11)	9.1± 0.31	10.8	(5-7)

RT-314XLCT	9.8 ± 0.24	7.95	(9-11)	6.9± 0.23	10.57	(6-8)
GNTXLVG	10.4 ± 0.16	4.90	(10-11)	7.6±0.21	9.07	(6-8)
LVG	12 ± 0.44	11.75	(7-15)	10.6±0.49	14.81	(4-6)
LVGXLCT	11.8 ± 0.53	14.23	(9-14)	7.6±0.37	12.63	(7-9)
LVGXGNT	10.9 ± 0.40	11.74	(9-13)	6.6±0.39	19.09	(6-9)

*Based on 25 unit areas under a compound microscope.

**Based on 100 guard cells per variety.

*a The mean difference between all hybrids is statistically significant at 5% level. The mean difference b/w all hybrids, with the exception of LCT X LVG and LCT X GNT, is significant at the 1% level.

b. The mean difference between all hybrids isstatistically significant at 5% level. The mean difference b/w all hybrids and their parents is substantial at the 1% level.

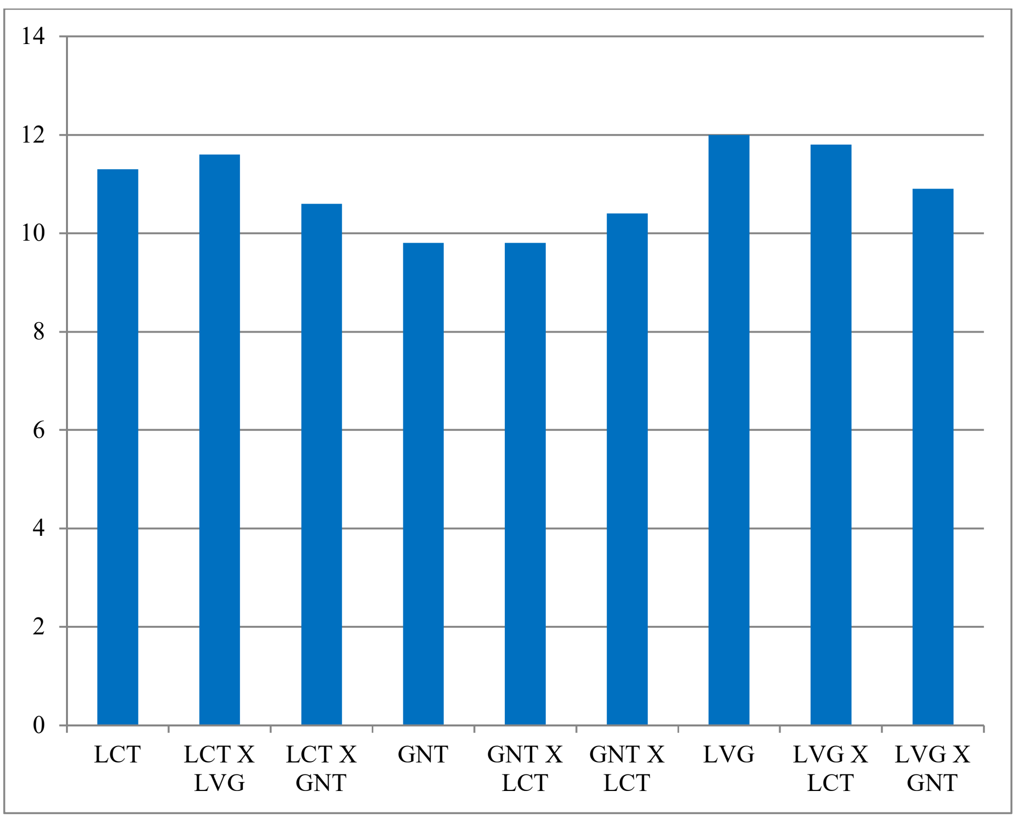


FIGURE 4.30 : MEAN OF NUMBER OFSTOMATA PER UNITAREA IN F1 INTERVARIETAL AND PARENTAL FORMS

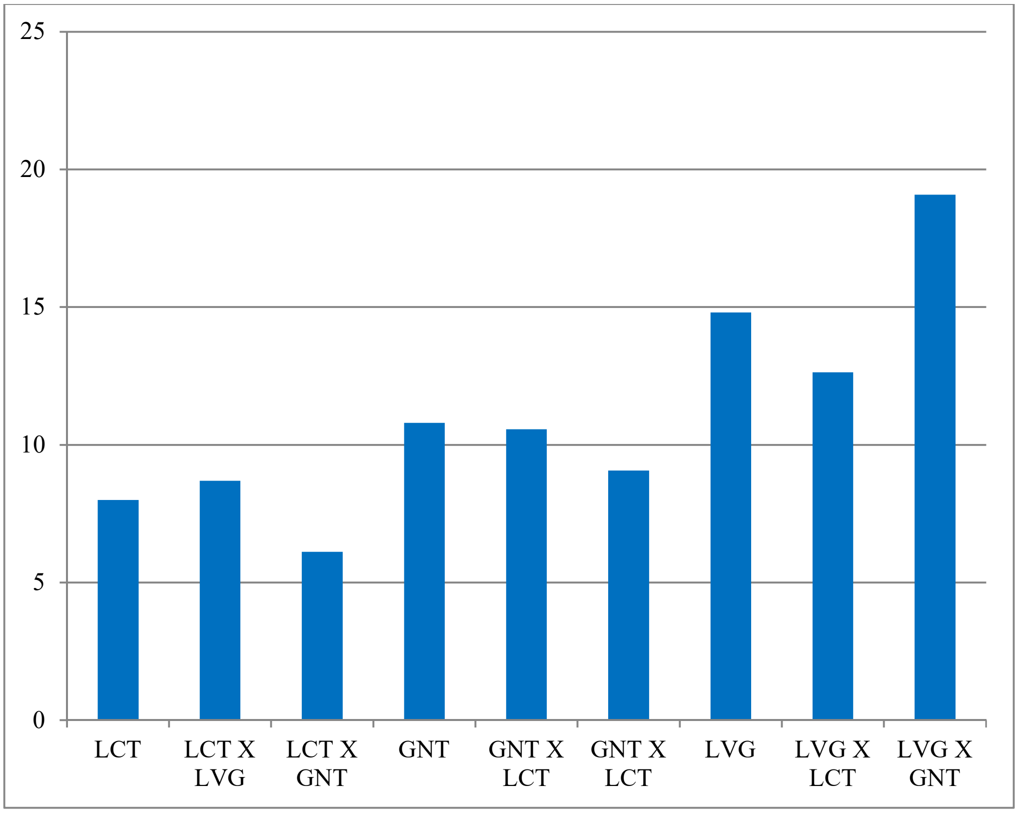
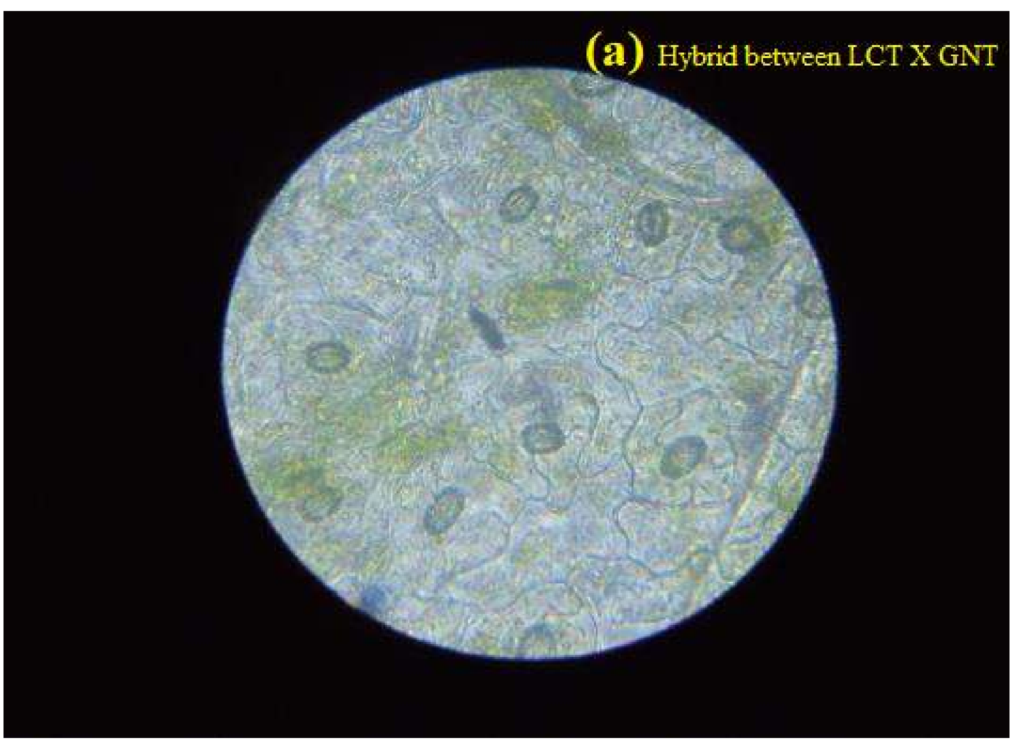
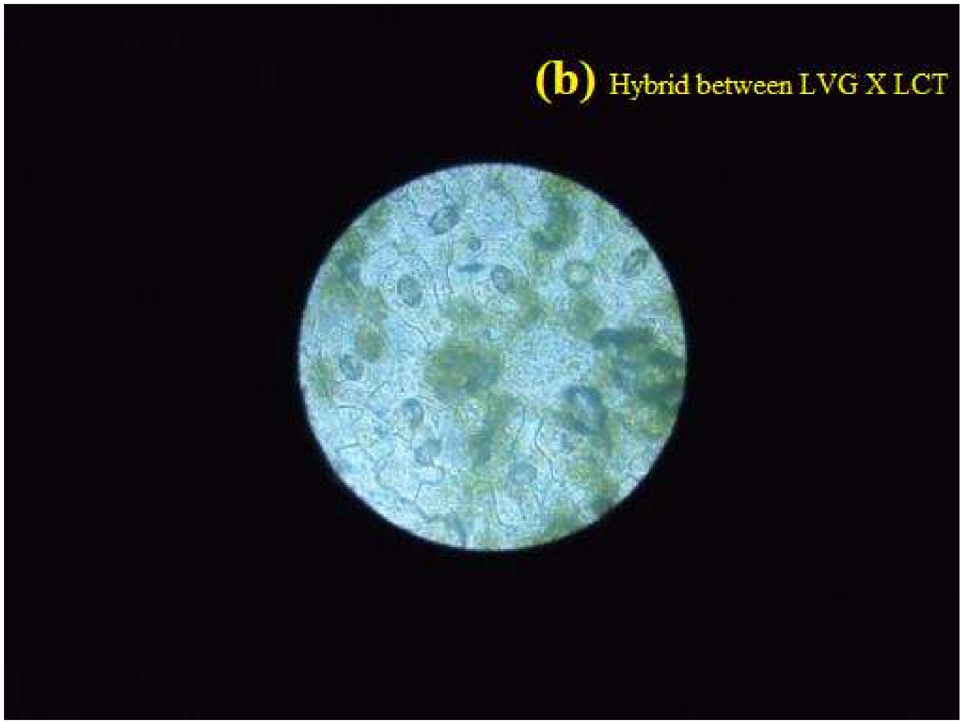
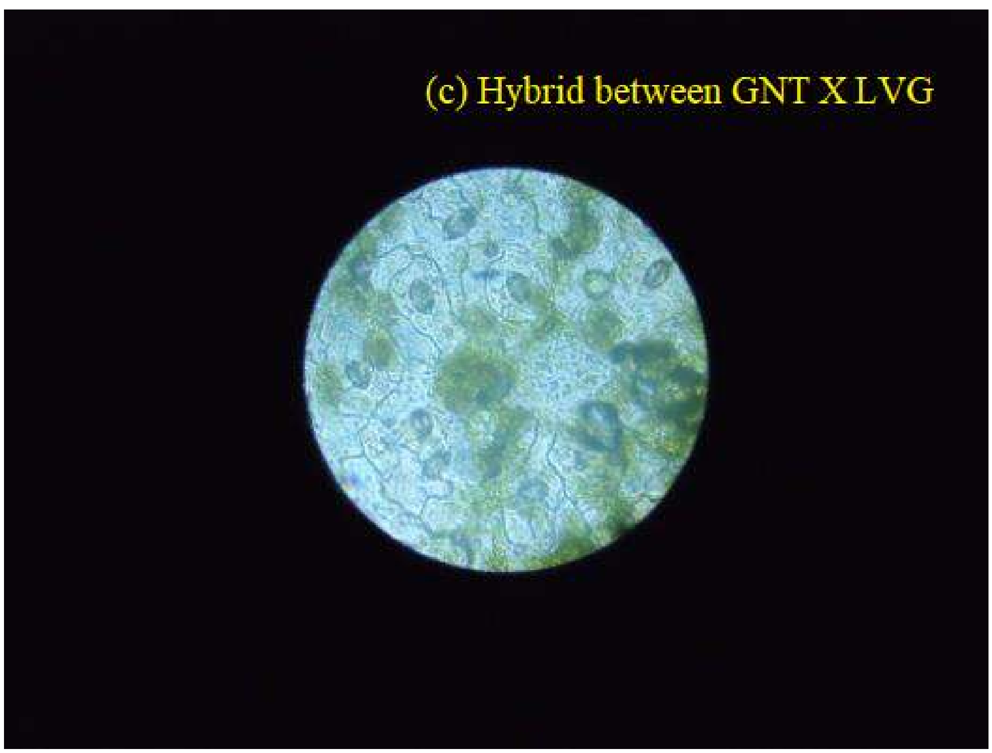


FIGURE 4.31: MEAN OF NUMBER OF CHLOROPLASTS PER GUARD CELL




(b) Hybrid between LVG X LCT


(c) Hybrid between GNT X LVG

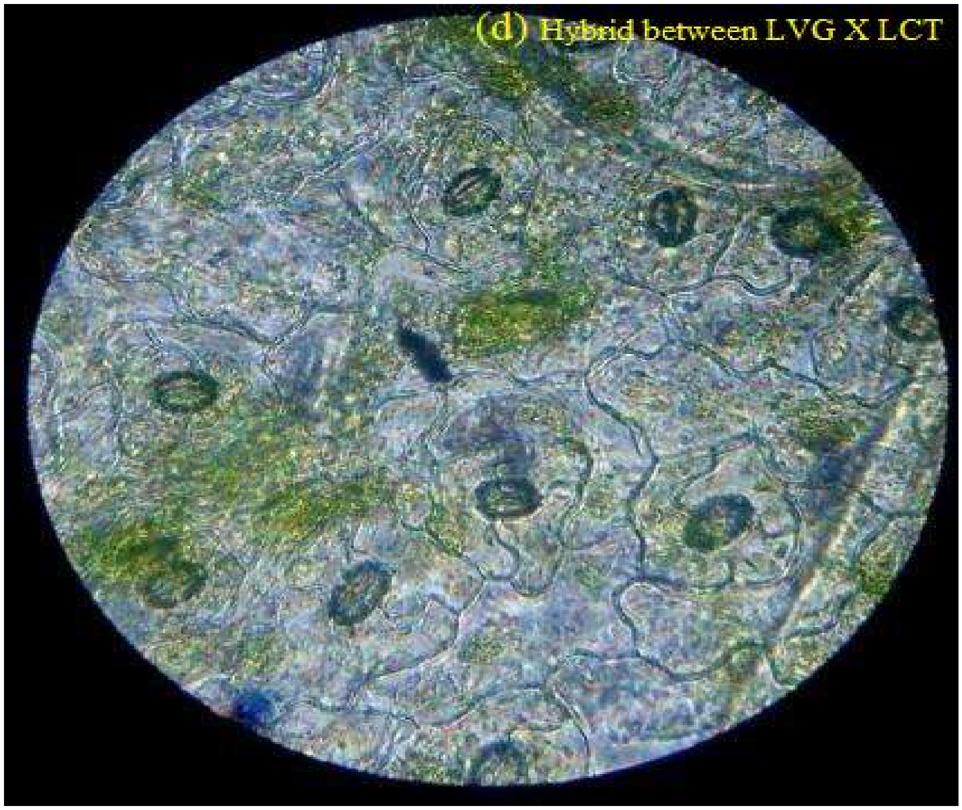


FIGURE 4.32: NUMBER OFSTOMATA PER UNITAREA

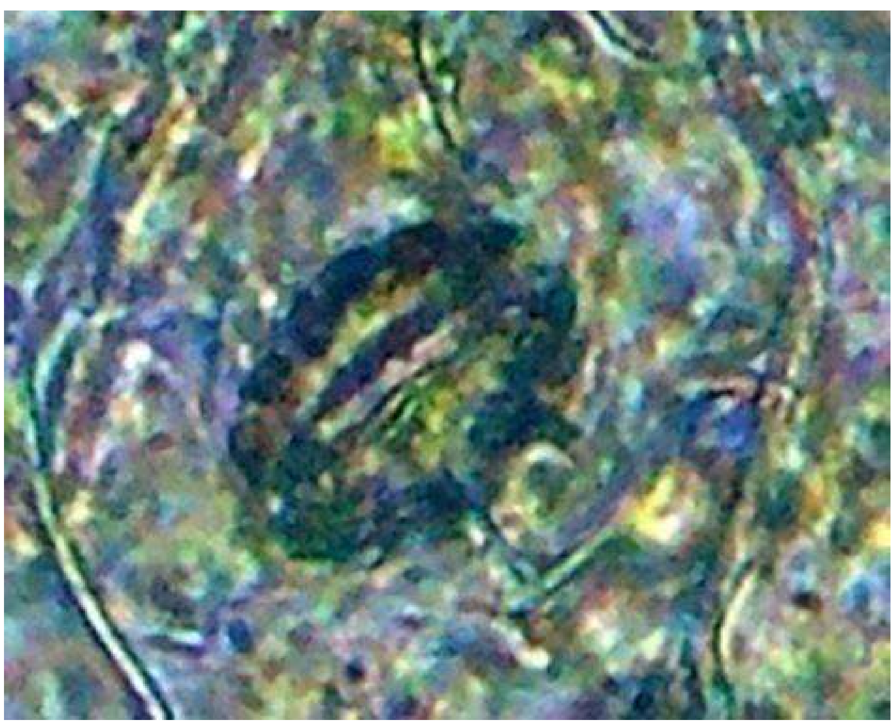


FIGURE 4.33: NUMBEROF CHLOROPLAST PER GUARDCELL

4.7.6 FERTILITY CHARACTERS

One of the goals of this study was to look at fertility in several Rocket cultivars and their F1 hybrids. Here is a comparison of several fertility-related parameters, such as average number of ovules per pistil & number ofseeds per silique.

4.7.6.1 MEAN NUMBER OFOVULES/ PISTIL

The meannumber of ovules perpistil was determined as previously stated. It was also demonstrated earlier that mean number of ovules was quite consistent & typical for a variety. It was observed that all intervarietal hybrids had considerably higher means than their parental forms.The hybrid plants were likewise uniform in this regard. The average number of ovules in LCT × LVG, GNT × LCT, and GNT × LVG was greater than 30, with significant differences among them. The hybrid LVG × LCT has the lowest amount of ovules per pistil, distinguishing it from other hybrids. The six intervarietal hybrids showed substantial differences, with the exception of GNT × LVG and GNT × LCT. The quantity of ovules per pistil varied widely among varieties and intervarietal hybrids.

The co-efficient of variation in intervarietal hybrids differed from their parental forms. The hybrid LCT × LVG had the highest percentage of co-efficient of variation, whereas LVG × LCT had the lowest.

4.7.6.2 NUMBER OFSEEDS PER SILIQUE

Fertility in terms of seed set under open pollination was investigated in the varieties as well as their six intervarietal hybrids concurrently, and the findings are reported in a tabular format (Table 4.21 Fig. 4.35). To investigate the mean number of seeds/silique under open pollination, ten silique from each of the 20 plants of each variety, as well as the intervarietal hybrids, were harvested and carefully dissected with a fine blade to count number of seeds per silique, & the mean numberof seeds per silique was scored. It remained quite stable throughout both kinds and hybrids. It was discovered that all F1 hybrids had considerably higher mean values than their parental forms. All The hybrid LCT × LVG had the largest number of seeds/silique, followed by LVG × GNT with the lowest mean number of seeds/silique (23.82). The hybrid GNT and LVG had about the same mean.

The hybrids have a higher coefficient of variation when compared to The hybrids had an intermediate CV percentage. Compared to other intervarietal hybrids, GNT × LVG has the lowest CV%. The amount of seeds per silique varied widely across the types and intervarietal hybrids. It is worth noting that the hybrids demonstrated a greater range of diversity than their parents. LCT × LVG had the most variety in this regard, ranging from 1 to 39.

TABLE 4.21: MEAN NUMBER OF OVULES/ PISTIL, NUMBER OFSEEDS PER SILIQUE, FERTILITY VALUE IN DIFFERENT VARIETIES OF ROCKET AND THEIR F1 HYBRIDS

MATERIALS	NUMBEROF OVULES/PISTIL*a			NUMBEROF SEEDS/SILIQUE*b			FERTILITY VALUE (%)*c	
	MEAN ±SE	CV (%)	RANGE	MEAN ±S.E.	CV%	RANGE	MEAN ±S.E.	CV%
LCT	36.4±1.0	8.98	(26-36)	35.6±1.12	10	(22-35)	23.09±1.45	10.02
LCTXLVG	36.3±0.86	7.57	(32-41)	36.4±1.14	9.94	(31-42)	50.9±1.69	12.3
LCTXGNT	37.6±1.07	9.04	(32-40)	35.5±1.06	9.49	(30-41)	59.8±1.56	11.06
GNT	36.8±1.00	8.66	(26-39)	33.9±1.09	9.53	(26-38)	28.83±1.45	8.01
GNTXLCT	37.4±0.94	2.51	(32-40)	31±1.12	11.44	(29-40)	66.9±1.57	14.05
GNTXLVG	38.1±0.87	7.24	(33-40)	34.8±1.16	10.54	(28-39)	64.8±1.41	11.03
LVG	29.9±0.54	5.75	(24-32)	27.8±0.50	5.51	(21-32)	23.65±0.97	18.01
LVGXLCT	30.8±0.48	5	(28-33)	29.2 ±0.50	5.51	(28-31)	51.3±1,57	11.03
LVGXGNT	29.4±0.63	6.83	(26-33)	29.3±0.49	5.32	(27-32)	52.8±1.48	12.01

*Based on 20 plants per form.

a. The mean difference between all hybrids, except LVG X LCT and LVG X GNT, is significant at the 1% or 5% level. All hybrids, save LVG X LCT and LVG X GNT, had a significant mean difference from their respective parents at the 5% level.

*b. The mean difference between all hybrids is statistically significant at 1% or 5% level. The mean difference b/w all hybrids and their respective parents is noteworthy at the 1% or 5% level.

*c. The mean difference between all hybrids isstatistically significant at 5% level. The mean difference b/w all hybrids and their parents is substantial at the 1% level.

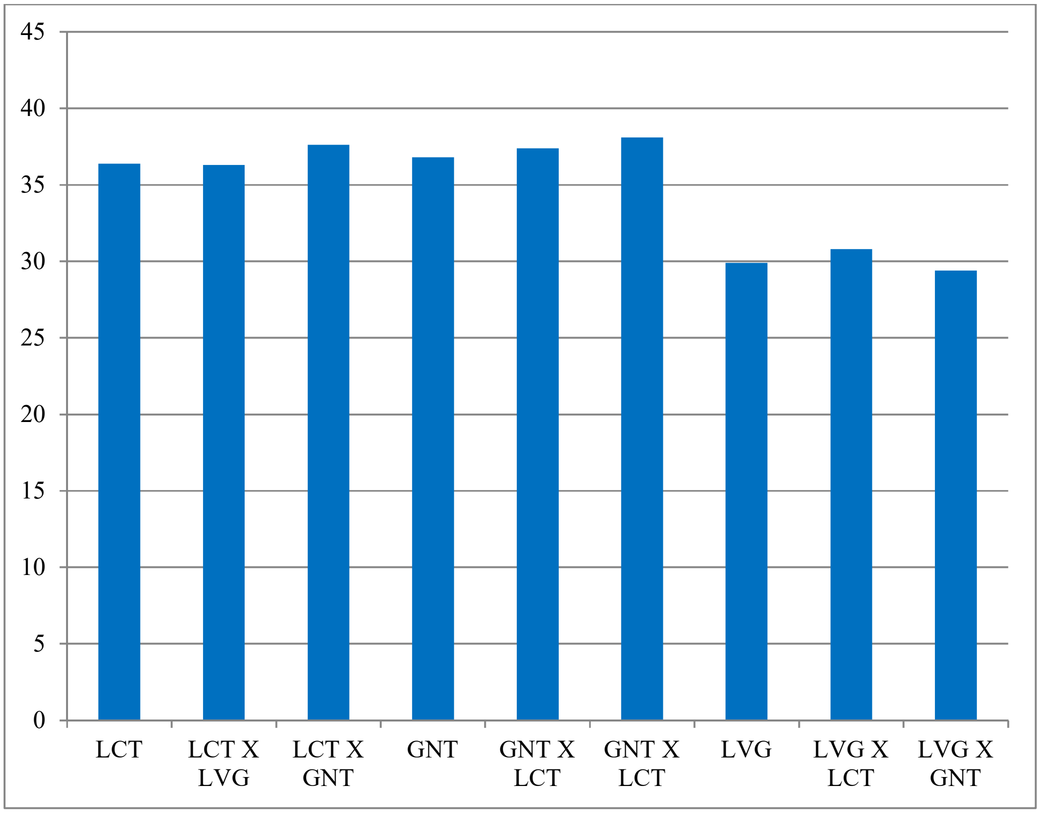


FIGURE4.34: MEAN OF NUMBER OF OVULES PER PISTIL IN F1 INTERVARIETAL AND PARENTAL FORMS

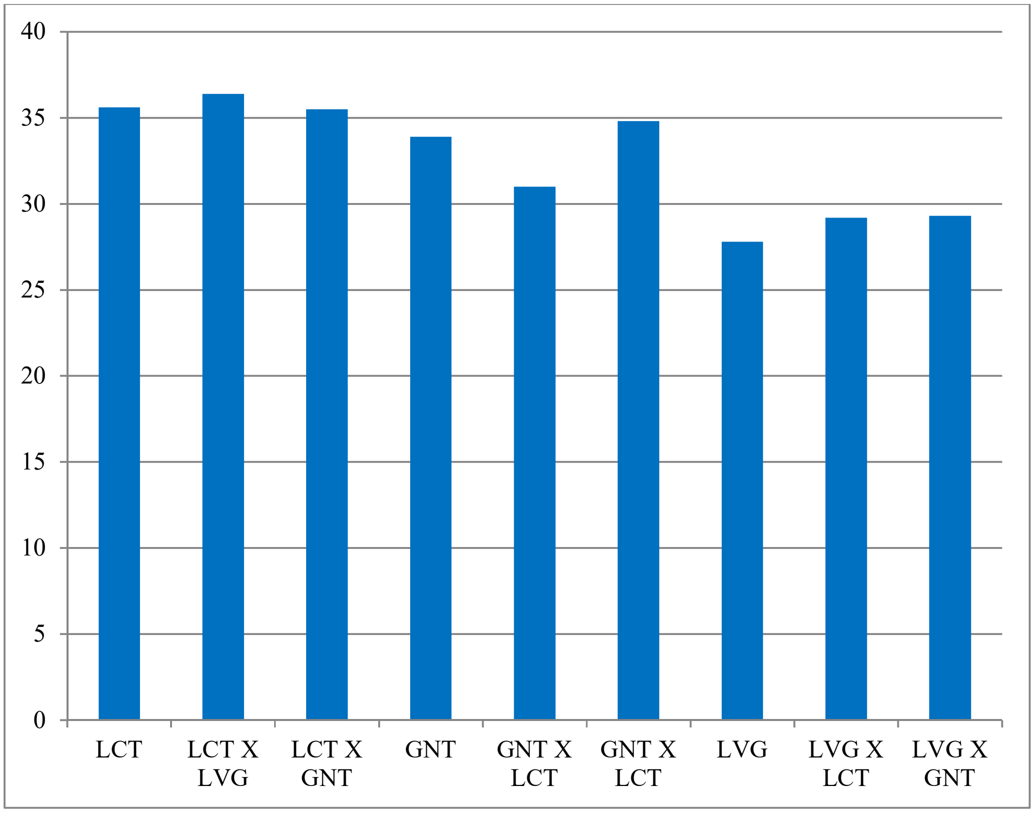


FIGURE 4.35: MEAN OF NUMBER OF SEEDS PER SILIQUE IN F1 INTERVARIETAL AND PARENTAL FORMS

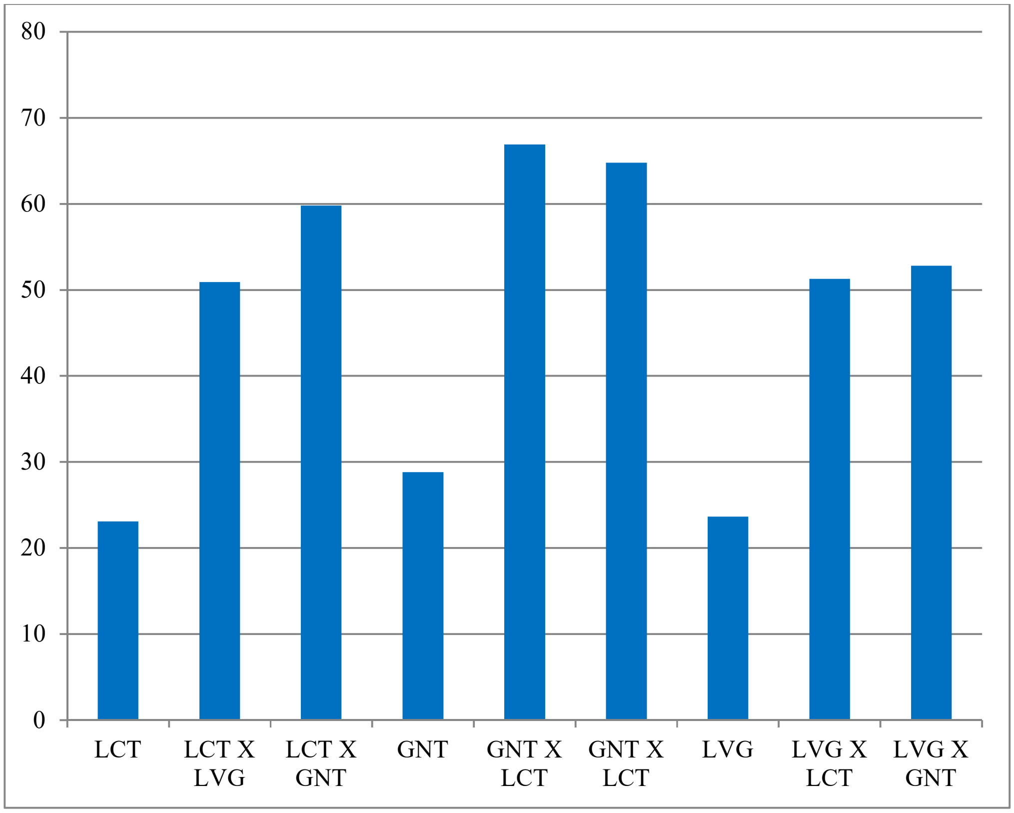


FIGURE 4.36: MEAN OF FERTILITY VALUE IN F1 INTERVARIETAL AND PARENTAL FORMS


(a) LCT


(b) LVG


(c) Hybrid of LCT X LVG


(d) LVG

FIGURE 4.37: SILIQUE OF DIFFERENT VARIETIES OF ROCKET

4.8 COMPARATIVE CYTOLOGICAL STUDIES OF DIFFERENT VARIETIES OF ROCKET AND THEIR F1 HYBRIDS

Cytological examinations were conducted in the six cultivars and their F1 hybrids, with a focus on chromocenters and pollen viability.

4.8.1 CHROMOCENTERS

Rocket is well-suited for studying the chromocenter. These are dark-stained heterochromatic entities seen in interphase nuclei. They represent constitutive heterochromatin. The study of chromocenters is critical for understanding the structure and organization of the nucleus. It may also aid in understanding the mechanism of chromosomal pairing and gene regulation, as constitutive heterochromatin is known toplay a critical part in these processes.

The amount of dark-staining heterochromatin bodies or chromocenters was counted in stigma's flask-shaped receptive cells. Although chromo centers were found in all types of cells. Receptive stigma cells were purposefully chosen for chromocenter counts due to two main considerations. For starters, responsive cells had flask-shaped ends and could therefore be clearly differentiated; secondly, the chromo centers in them were bigger in size, stained better, and countable.

Several chromocenters in form of heteropycnotic entities were discovered in the interphone nuclei ofthese cells. They also ranged in size. A pair of chromocenters was discovered linked to the nucleus.

In both years ofresearch, number of chromocenters per nucleus varied substantially, ranging from the mean (22 to 30) in various types. These types differed considerably in distribution and mean number of chromosomes per nucleus (Table 4.22, Fig. 4.38). It was fascinating to see that the average number of chromocenters was quite consistent across all kinds. However, their distribution pattern varied slightly. GNT has the smallest average number of chromocenters. LVG had the largest number among all the kinds. There was nosignificant difference in mean number of chromocenters b/w LVG ×

GNT & LVG × LCT, with all having almost the same mean. Interestingly, LVG varied greatly from the other types in this characteristic.

Individual plants within a variety also had significant diversity in the number of chromocenters per nucleus.

TABLE 4.22: NUMBER AND DISTRIBUTION OF CHROMOCENTRE IN THE PARENTAL AND THEIR F1 HYBRIDS IN ROCKET

MATERIALS	NUMBER OF CHROMOCENTER PER NUCLEUS*a			
	MEAN	±	S.E.	CV%
LCT	24.9	±	0.31	3.97
LCTXLVG	18.3	±	0.36	6.28
LCTXGNT	17	±	0.44	8.29
GNT	20.8	±	0.41	6.29
GNTXLCT	17.4	±	0.21	3.96
GNTXLVG	18.4	±	0.33	5.81
LVG	27.7	±	0.32	3.70
LVGXLCT	22.4	±	0.47	6.63
LVGXGNT	21.7	±	0.42	6.12

*Based on 20 nuclei per plant.

*a. The mean difference between all types, save LCT, is significant at the 1% level.

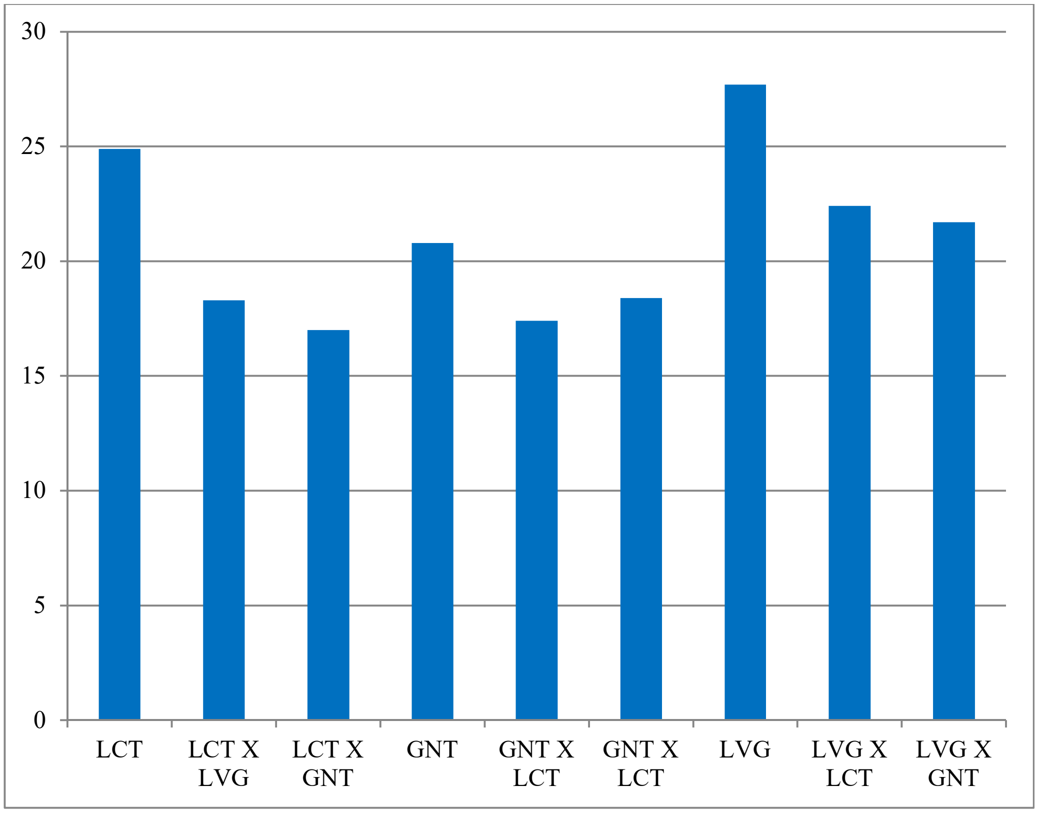
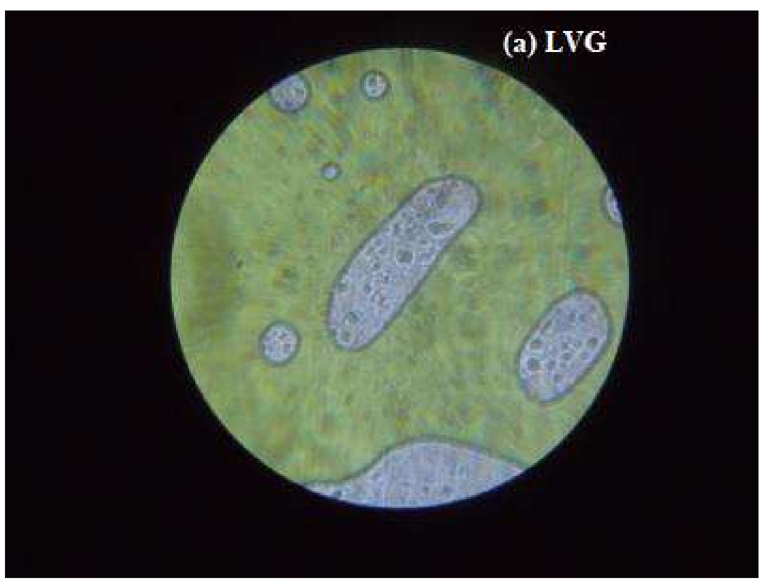
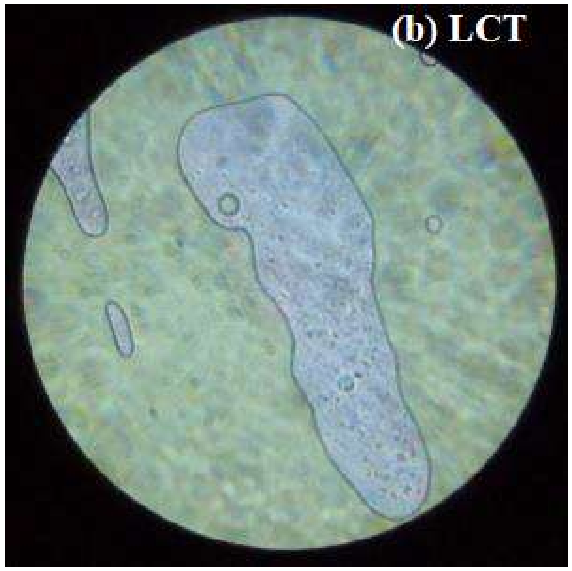
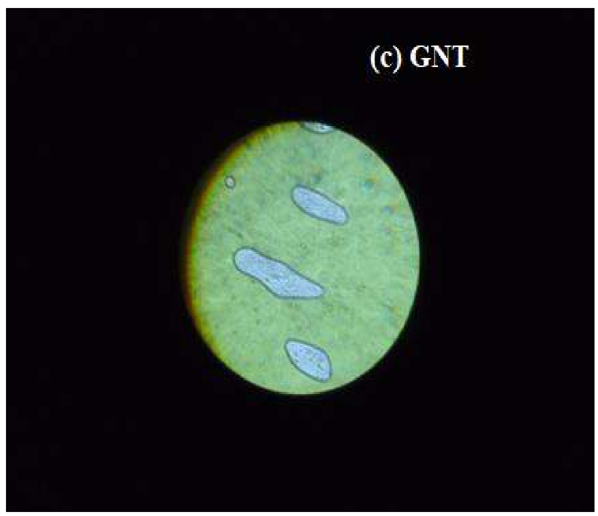


FIGURE 4.38: NUMBER OF CHROMOCENTER IN THE PARENTAL AND THEIR F1 HYBRIDS IN ROCKET




(b) LCT


(c) GNT

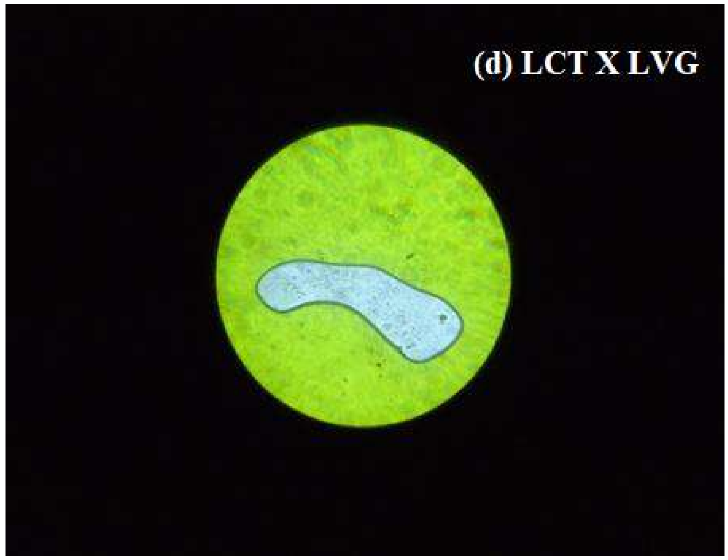


FIGURE 4.39: NUCLEI OF RECEPTIVE CELLS OF STIGMA SHOWING DIFFERENT NUMBER OF CHROMOCENTERS

4.8.2 POLLEN VIABILITY

Pollen viability was investigated using John Ferreira's (1985) approach. Approximately 1000 pollen grains were scored from each variety and the inter-varietal hybrid. Pollen viability varied significantly across variables (Table 4.23, Figure 4.40). This trait was more or less consistent across all 25 plants in a variety. Interestingly, all six types of Indian Rocket had a pollen viability of more over 40%. The variety GNT had the lowest pollen viability in both years of testing, followed by LVG and LCT.

The variety LCT had the greatest percentage of pollen viability of all the variations. It was interesting to see that the varieties did not do well in terms of pollen viability during both years of testing. This might be attributable to the environmental circumstances in those years.

Pollen viability in intervarietal F1 hybrids was marginally increased compared to parental forms (Table 4.23, Fig. 4.40). The research revealed that all intervarietal hybrids had higher pollen viability than their parental forms, exceeding 45%. Almost all F1 hybrids diverged greatly from their parent types. The hybrid LCT X LVG had the greatest percentage of pollen viability (%) and outperformed all other inter varietal hybrids except LCT × GNT, which ranked second in this criterion.

TABLE 4.23: POLLEN VIABILITY IN DIFFERENT VARIETIES OF ROCKET AND IN THEIR F1 HYBRIDS

MATERIALS	POLLEN VIABILITY*		
	MEAN	±S.E.	CV%
LCT	43.5	±0.82	5.95
LCTXLVG	45.5	±0.30	2.13
LCTXGNT	46.5	±0.30	2.08
GNT	49.5	±0.34	2.18
GNTXLCT	51.2	±0.62	3.86
GNTXLVG	56.3	±1.09	6.14
LVG	49.7	±0.29	1.89
LVGXLCT	53	±0.33	1.98
LVGXGNT	52	±0.36	2.21

*Based on 100 pollen per variety.

Except for GNT X LVG and GNT X LCT, there is a substantial variation in mean pollen viability between all types at the 1% level.

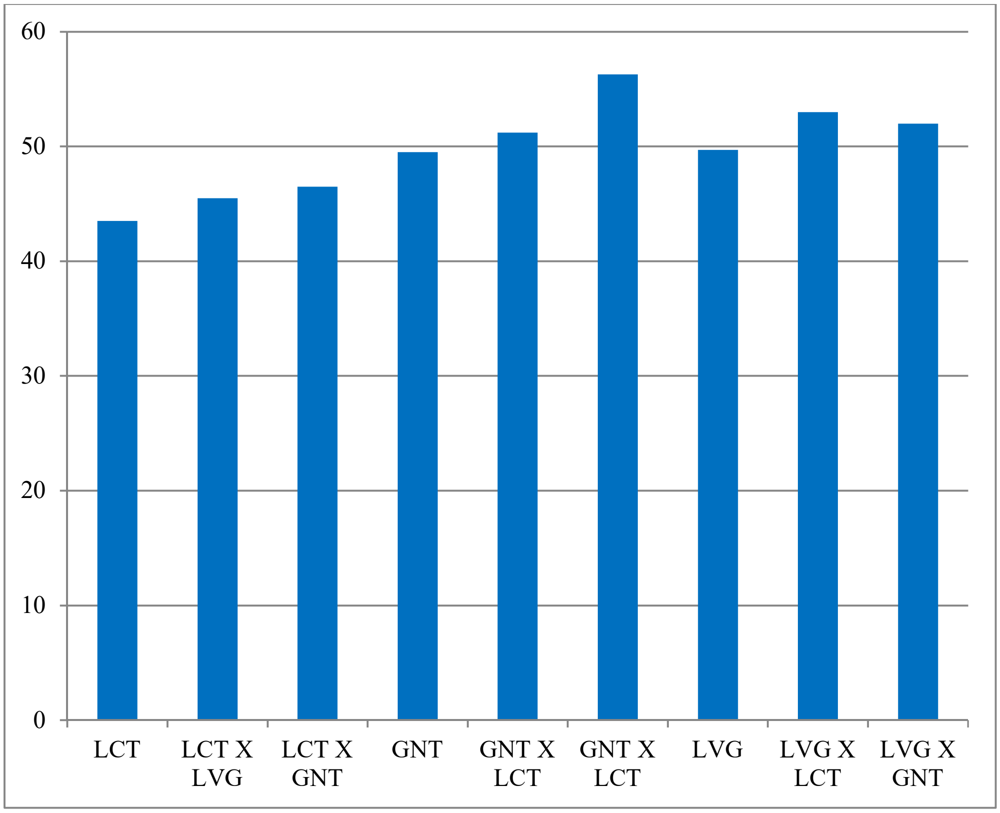
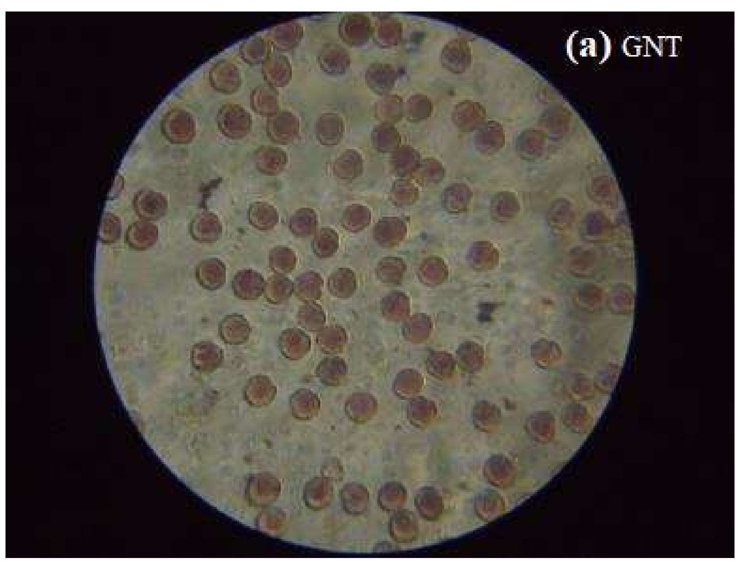
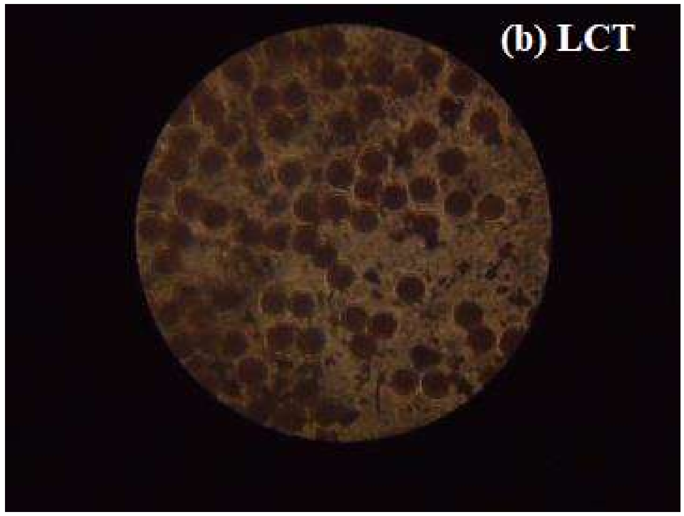
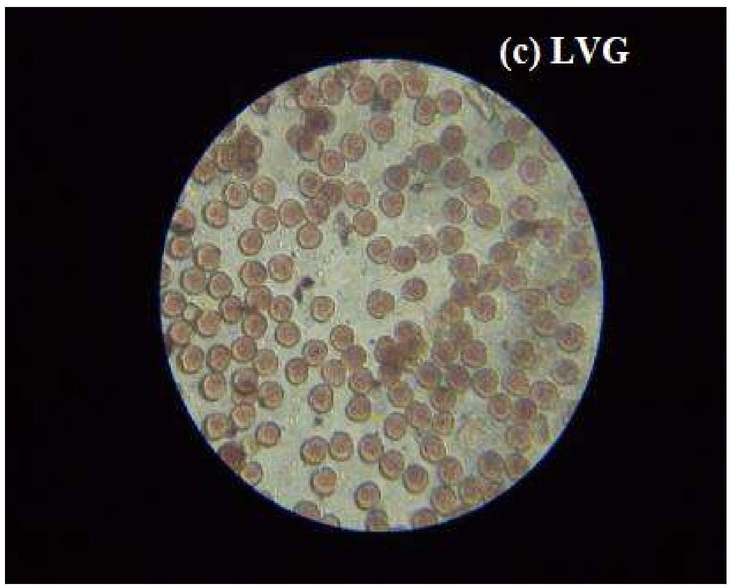
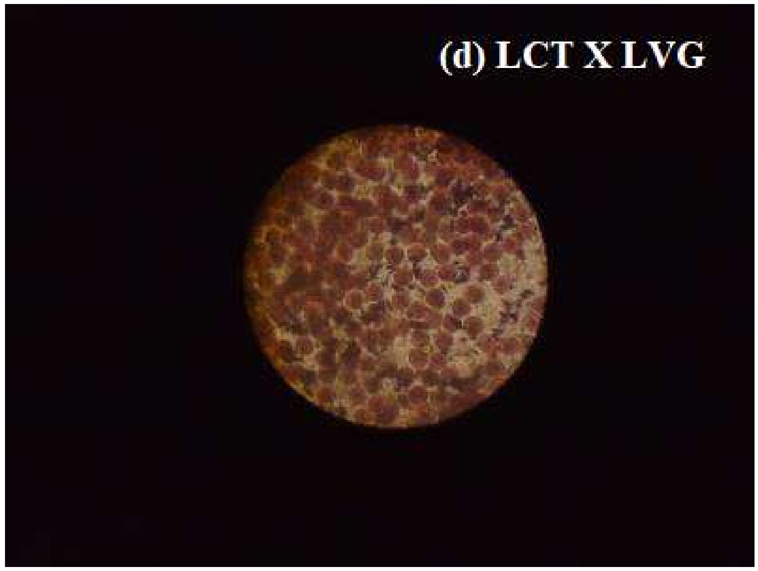


FIGURE 4.40: POLLEN VIABILITY IN THE PARENTAL AND THEIR F1 HYBRIDS IN ROCKET




(b) LCT


(c) LVG



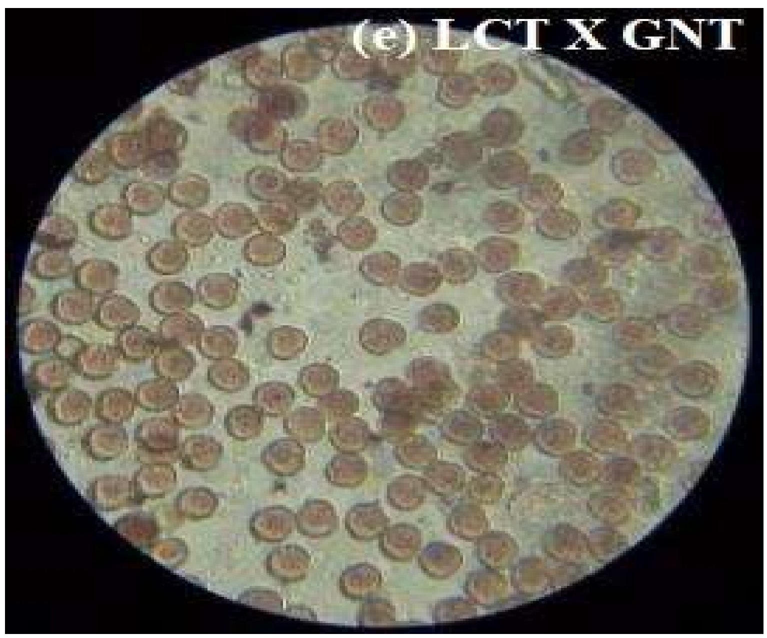


FIGURE 4.41: VIABLE AND NONVIABLE POLLENS IN THE PARENTAL AND THEIR F1 HYBRIDS IN ROCKET

4.9 PHYSIOLOGICAL STUDIES

4.9.1 RATE OF TRANSPIRATION

Transpiration is release of surplus waterfrom plants in form ofwater vapour. To analyze this characteristic in the Rocket plant's F1 hybrids, a minute observation is made by tracking the movement of the water bubble over a set time period. It was shown that

LCT X GNT had the greatest rate of transpiration, followed by LVG X GNT. The lowest rate of transpiration was recorded by LCT X LVG

TABLE 4.24: RATE OF TRANSPIRATION IN PARENTAL FORMS OF ROCKET AND THEIR F1 HYBRIDS

MATERIALS	TIME TAKEN CONSTANT (30min)	BASED ON 10OBSERVATION				RATE OF TRANSPI RATION
		Distance moved	MEAN	± S.E.	C.V. (%)	
LCT	12:30 to 1:00pm	14	11.7	± .36	9.34	.36
LCT X LVG	1:00 to 1:30pm	12	12.3	± .36	9.31	.40
LCT X GNT	12:40 to 1:10pm	15	13.1	± 5.57	.23	.05
GNT	1:10 to 1:40pm	12	12.0	± .33	8.75	.46
GNT X LCT	1:00 to 1:30pm	13	11.0	± .25	7.36	.43
GNT X LVG	12:30 to 1:00pm	12	11.7	± .29	8.03	.40
LVG	1:00 to 1:30pm	10	12.0	± .36	9.58	.36
LVG X LCT	12:30 to 1:00pm	10	11.9	± .39	11.05	.33
LVG X GNT	12:00 to 12:30pm	11	11.7	± .36	10.26	.36

*Based on ten observations.

The mean difference between all the hybrids is significant to each other at the 1% or 5% level, and to their parent at the 1% level.

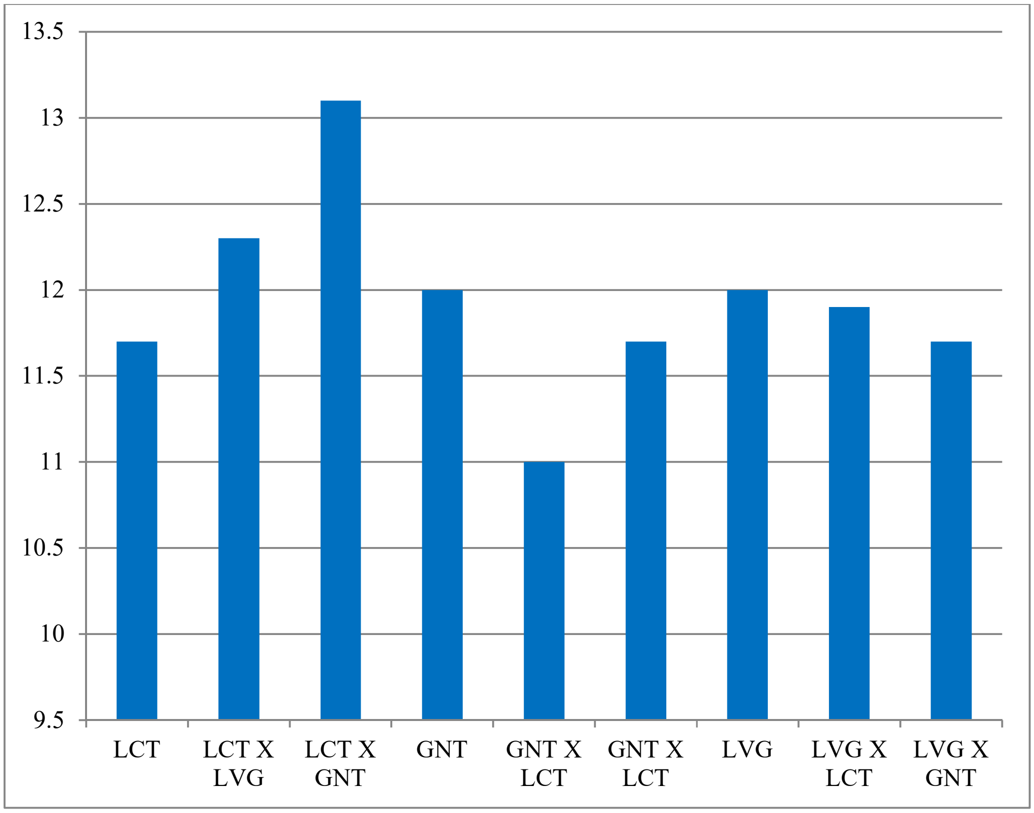


FIGURE 4.42: RATE OF TRANSPIRATION IN PARENTAL FORMS OF ROCKET AND THEIR F1 HYBRIDS

CHAPTER 5
FINDINGS ANDCONCLUSIONS

5.1 FINDINGSOF THE STUDY

1. The rocket varietal populations under study differ genotypically in a variety of morpho-physiological characteristics: Percentage seedgermination Mean hypocotyllength, mean cotyledonarea, relative cotyledon width, numberof leaves perplant, numberof leaf lobes, numberof stomata per unit area, number of chloroplasts per guard cell, number of branches perplant, plant height, transpiration rate, and days to flower.
2. F1 inter varietal hybrids outperform their parents in certain morphophysiological characteristics. This might be related to heterosis caused by their higher heterozygosity. This also suggests a degree of genotypic control for certain traits.
3. The varietal populations differ in terms of crossability. The crossability of LCT and LVG was poor, indicating a genetic distance between them.
4. The types differ in terms of average number of ovules and seeds, as well as Fertilization value. The excellence of their F1 hybrids in several traits reflects not only heterosis but also genotypic control.
5. The mean number and location of chromocenters in interphase nuclei also vary. This nuclear trait varies amongst varietal populations.
6. The number of chromosomes in the F1 intervarietal hybrids is about equal to that of their parents. This nuclear phenotype appears to be genotypically regulated. Varieties with fewer chromocenter classes outperform those with more of them.
7. Pollen viability differs across kinds. The F1 hybrid has better pollen than its parent.
8. Mean number of chromocenters is polygenically regulated in rocket

5.2 CONCLUSIONS

Eruca sativa, amember of Brassicaceae family, isan annual herbaceous plant. The plant is prevalent across the Mediterranean region, including Greece, Italy, and Turkey. This plant is classified an endemic species since it is only found in a few distinct places. Rocket has historically been utilized as a herb or spice, as well as a garden plant (Yaniv et al.,1998). Accordingto statistics from TurkishStatistics Foundation (TUIK) for year, rocket output in Turkey was expected to be around 4058 tons, which were consumed either cooked in various meals or raw in salads. Aside from nutrition, rocket is employed in the health and cosmetics sectors due to its potent phytochemical properties.

A search of historic literature from ancient classical & Islamic sourcesup to Middle Ages and Israel, including Jewish texts, revealed that the plant was also employed as a spice and garden produce throughout that time period. It wasalso renowned as aplant with medical properties as an aphrodisiac,for digestive & renal issues, and for eye infections. Historically, there was a focus on the diversity of rocket species. Its natural accessions and high erucic acidcontent were gathered & analyzed as apotential future supply of industrialoil.

Brassicaceae plants have grown in popularity over time due to their favorable benefits on human health, as they contain nutraceutical chemicals. The health-promoting components include glucosinolates and flavonoids. The plant has anti-inflammatory qualities due to the presence of specific nutraceuticals. Glucosinolates give rocket its distinct rich scent and flavor. Because of its medicinal benefits in traditional medicine, ancient and modern academics appreciate it as a diuretic and digestive agent, as well as for treating renal and skin ailments. There is significant interest among researchers who use rocket as a lubricant or biofuel crop.

The plant's leaves are a seasonal pleasure, offering peppery, crisp, and sensitive nibbles. The plants have a distinctive mild flavor & a spicy hottaste. Rocket has a high metabolic rate, and like most green vegetables, it can create a lotof ethylene afterharvest. However, because to its high surface-to-volume ratio & perishability, quality losses are very sensitive. The plant has a high respiration rate, which may cause yellowing of the leaves and plant due to chlorophyll degradation, resulting in a loss in quality and shelf life.

To avoid quick quality deterioration, the leaves and packaging must be stored with care. Photochemical tests on several portions of Eruca sativa indicate the presence of chemicals, alkaloids, flavonoids, cardiac glycosides, and so on.

The rocket plant's leaves are extensively lobed, with 4 to 10 little lateral lobes and big terminal lobes. The flower is organized in a corymb, as is characteristic for Brassicaceae. The blooms are 2 to 4 cm in diameter. The blooms are either creamy with white purple veins or yellow petals with yellow stalks. The fruit is a silique, measuring 12 to 25 mm in length and with an apical beak. The silique contains numerous seeds that contain oil and are edible. This species' chromosomal number is 2n = 22.

The term sativa in plantbinomial is a Latin adjective derived fromsatum, supine of verb sero, meaning tosow, indicating that plants' seeds may be sowed in the garden. Rocket may thrive even on dry, disturbed ground. The plant root is sensitive to nematodes. The plant is a leafy greenvegetable that resembles longer-leafed open lettuce. In India, ripe seeds are referred to as gargeer.

The rocket plant is well renowned for its crisp, peppery flavor and is widely used as a salad vegetable. Rocket demand has surged in recent years as consumers seek a healthy, conveniently available food. Fresh rocket leaves are strong in antioxidants and alkaline. Certain phytochemicals have protective and preventative qualities.

Rocket is a major vegetable crop, but it has received little attention from cytologists, geneticists, and plant breeders. Many earlier works on crop Brassies have been published by various authority, each addressing a distinct issue. Despite the fact that the genetic structure of Rocket varietal populations is extremely important in plant breeding, we currently have very little knowledge on it.

The current study considers many morphological, physiological, and cytological characteristics. The goal of the research is to achieve heterosis through hybridization. The following parameters were evaluated during the current investigation:

SEEDLING MORPHOLOGY - Seedling morphology was investigated by planting 200 seeds of each type in separate iron trays, filling them with uniform soil, and irrigating them at regular intervals. 100 mature seedlings of each variety and F1 intervarietal hybrids were chosen at random to investigate hypocotyl morphology. At the same time, length & breadth of cotyledons weremeasured using a division & scale. The mean cotyledon was determined by multiplying length & breadth of cotyledons.

MEAN NUMBER OFLEAVES - The total numberof radical leaves in 25 plants from each variety and their intervarietal hybrids was counted shortly before the flowering stalk emerged.

MEAN NUMBER OF LEAF LOBES - The number of leaf lobes in 10 radical leaves from 25 plants of each variety and hybrid was counted.

MEAN NUMBER OF BRANCHES - Twenty-five plants of each variety and hybrid were counted to determine number of secondarybranches growing from the primary axis.

PLANT HEIGHT - The height of 25 plants from each variety and hybrid was measured shortly before harvesting.

DAYS TO FLOWER - The day when the first blossom appeared was measured.

NUMBER OF STOMATA / UNIT AREA - The number of stomata detected in a single microscopic field was recorded.

NUMBER OFCHLOROPLASTS / GUARDCELL - The total numberof chloroplasts in each guard cell wasdetermined bycounting 50 cells from each variety and hybrid.

MEAN NUMBER OFOVULES / PISTIL - The mean number ofovules was determined by analyzing 100 pistils from each variety and hybrid.

AVERAGE NUMBER OF SEEDS/SILIQUE - Ten siliques from each of the 20 plants of each type were picked and meticulously dissected using a tiny blade and needles to count number of seeds, and mean wascalculated.

The rocket varietal populations studied here differ genotypically in a variety of morpho-physiological characteristics. F1 intervarietal hybrids outperform their parents in all morpho-physiological characteristics, which can be regarded an example of heterosis due to enhanced heterozygosity.

BIBLIOGRAPHY

1. Blamey, M. & Grey-Wilson, C. (1989). Flora of Britain and Northern Europe. ISBN 0-340-40170-2.
2. Yaniv, Zohara; Schafferman, D.; Amar, Z. (1998). "Tradition, Uses and Biodiversity of Rocket (Eruca sativa, Brassicaceae) in Israel". Economic Botany. 52 (4): 394–400. doi:10.1007/BF02862069. JSTOR 4256115. S2CID 36181033.
3. "Flora Europaea Search Results". rbge.org.uk.
4. Claiborne, Craig (May 24, 1960). "A Green by Any Name: Pungent Ingredient Is Cause of Confusion for City Shopper; Arugula – or Rocket – Is the Secret of Experts' Salads". The New York Times. p. 33.
5. "Arugula: Arugula". smartgardener.com.
6. NutritionData.com, Arugula, Raw
7. Upton, Julie, RD. "7 Foods for Better Sex". Health.com. Archived from the original on April 10, 2015. Retrieved July 5, 2010.
8. Wright, Clifford A. (2001). Mediterranean Vegetables. Harvard Common Press. p. 27. ISBN 9781558321960.
9. Virgil, 102 Moretum: 85. Joseph J. Mooney in his 1916 English translation, "The Salad", calls it "colewort" and notes, "The Latin "moretum", which is usually translated "salad", would be better called "cheese and garlic paste", i.e., pesto. See The Minor Poems of Vergil: Comprising the Culex, Dirae, Lydia, Moretum, Copa, Priapeia, and Catalepton (Birmingham: Cornish Brothers, 1916), scanned as part of Appendix Vergiliana: The Minor Poems of Virgil in English Translation on the website Virgil.org.
10. Ovid, The Love Poems (Oxford 2008) p. 119
11. Padulosi, Pignone D., Editors, Rocket: A Mediterranean Crop for the World (International Plant Genetic Resources Institute,1997), p. 41.
12. Helen Morgenthau Fox, Gardening With Herbs for Flavor and Fragrance (1933, reprinted New York: Dover, 1970), p. 45. See also Denise Le Dantec and Jean-Pierre Le Dantec, Reading the French Garden: Story and History (MIT Press, 1998), p. 14.

13. Missiry –EL, MA., & Gindy – EL, AM. (2000). Amelioration of alloxan induced diabetes mellitus and oxidative stress in rats by oil of Eruca sativa seeds. Annals of Nutrition and Metabolism, 44(3), 97-100.

14. Miyazawa, M., Maehara, T. & Kurose, K. (2002). Composition of the essential oil from the leaves of Eruca sativa. Flavour and fragrance journal, 17(3), 187-190.

15. Vilamil, J. M. P. (2002). Time of seed collection and germination in rocket, Eruca vesicaria (L.). Genetic Resources and Crop Evolution 45, 47-51.

16. Asharaf, M. A., & Sarwar, G. (2002). Salt tolerance potential in some members of Brassicaceae physiological studies on water relations and mineral contents. Prospects for saline agriculture, 237- 245.

17. Sastry, EV. (2003). Improvement in Eruca sativa L. Aricultural Reviews, 24(4), 235-249.

18. Mahmood, S. et. al. (2004). Comparative performance of Brassica napus and Eruca sativa under water deficit conditions : An assessment of selection criteria. J. Res. Sci, 14(4), 439-446.

19. Barillari, J. et. al. (2005). Direct antioxidant activity of purified glucoerucin, the dietary secondary metabolite contained in rocket seeds and sprouts. Journal of Agriculture and food chemistry, 53(7), 2475- 2482.

20. Fazli, IS., Abdin, MZ., Jamal, A., & Ahmad, S. (2005). Interactive effect of sulphur and nitrogen on lipid accumulation and acetyl- CoA concentration and acetyl - CoA carboxylase activity in developing seeds of oilseed crops. Plant science 168(1). 29 – 36.

21. Larran, S., Ronco, L., Monaco, C., & Andreau, RH. (2006). First report of Peronospora parasitica on rocket in Argentina. Australasian plant pathology 35(3), 377-378.

22. Alam, S. M. et. al. (2007). Eruca sativa seeds possess antioxidant activity and exert a protective effect on mercuric chloride induced renal toxicity. Food and chemical toxicology , 45(6), 910-920.

23. Bennett, N. R. et. al. (2007). Identification and quantification of glucosinolates in sprouts derived from seeds of wild Eruca sativa and Diplotaxis tenuifolia L. Journal of agricultural and food chemistry 55(1), 67-74.

24. Bukhsh, E., Malik, A. S., & Ahmad, S. S. (2007). Estimation of nutritional value and trace elements content of Carthamus oxyacantha, Eruca sativa and Plantago ovate. Pakistan Journal of Botany, 39(4), 1181.

25. Sharma, D. K., Rana, D. S., Joshi, H. C. (2007). Evaluation of sugarcane (Saccharum officinarum) - based industrial waste and litter fall of jatropha (Jatropha curcas) for nutrient management in oliferous rocket salad (Eruca sativa). Indian Journal of Agronomy, 52(3), 160-163.

26. Manohar, S. S., & Sharma, K. C. (2008). Genetic variability and characters association analysis in Taramira (Eruca sativa Mill.). Madras Agricultural Journal, 95(7/12), 278-282.

27. Nielsen, T., Bergstorm, B., & Borch, E. (2008). The origin of off – odours in packaged rucola. Food chemistry, 110(1), 96-105.

28. Manohar, S. S., & Sharma, K. C. (2008). Genetic variability and characters association analysis in Taramira (Eruca sativa Mill.). Madras Agricultural Journal, 95(7/12), 278-282.

29. Alqasoumi, S. et. al. (2009). Rocket: A salad herb with potential gastric anti-ulcer activity. World Journal of Gastroenterology: WJG, 15(16), 1958.

30. Khan, S. & Qurainy. F. Al. (2009). Mutagenic effect of sodium azide on seed germination of Eruca sativa (L.). Australian Journal of Basic and Applied Sciences 3(4), 3081-3087.

31. Nicola, S., Fontana, E., Tibaldi, G., & Zhan, L. (2009). Qualitative and physiological response of minimally processed rocket (Eruca sativa Mill.) to package filling amount and shelf – life temperature. VI International Postharvest Symposium, 877, 611- 618.

32. Chakrabarti, H. M., & Ahmad, R. (2009). Investigation possibility of using least desirable edible oil of Eruca sativa L., in biodiesel production. Pakistan Journal of Botany, 41(1), 481-7.

33. Khan, S. & Qurainy. F. Al. (2009). Mutagenic effect of sodium azide on seed germination of Eruca sativa (L.). Australian Journal of Basic and Applied Sciences 3(4), 3081-3087.

34. Kumar, G. et. al. (2009). Physiological responses among Brassica species under salinity stress show strong correlation with transcript abundance for SOS pathway related genes. Journal of plant physiology, 166(5), 507-520.

35. Jing, J. et. al. (2009). Analysis of phytochemical composition and chemoprotective capacity of rocket (Eruca sativa and Diplotaxis tenuifolia) leafy salad following cultivation in different environments. Journal of Agriculture and Food Chemistry 57(12), 5227-34.

36. Ozdener, Y. & Ayadin, B. K. (2010). The effect of zinc on the growth and physiological and biochemical parameters in seedling of Eruca sativa L. Acta Physiologiae Plantarum , 32(3), 469-476.

37. Bozokalfa, K. M. et. al. (2011). Evaluation of phenotypic diversity and geographical variation of cultivated and wild rocket plant. Plant genetic resources 9(3), 454- 463.

38. Michael, H., Shafik, R. E., & Rasmy, G. E. (2011). Studies on the chemical constituents of fresh leaf of Eruca sativa extract and its biological activity as anticancer agent in vitro. Journal of medicinal plant research 5(7), 1184-1191.

39. Kasem, WT., Ghareeb, A., & Marwa, E. (2011). Seed morphology and seed coat sculpturing of 32 taxa of famiy Brassicaceae. Journal of American science, 7(2), 166-178.

40. Al-Whaibi, H. M. et. al. (2012). Influence of plant growth regulators on growth performance and photosynthetic pigments status of Eruca sativa Mill. Journal of Medicinal Plants Research, 6(10), 1948 – 1954.

41. Berba, J. Kenneth & Uchanski, E. M. (2012). Post harvest physiology of microgreens. J.

42. Mumtaz, A. S. (2013). Genetic divergence in taramira (Eruca sativa L.) germplasm based quantitative and qualitative characters. Pakistan journal of Botany, 45(SI), 375 -381.

43. Vannini, C. et. al. (2013). Morphological and proteomic responses of Eruca sativa exposed to silver nanoparticles of silver nitrate. Plos one, 8(7), 68752.

44. Suma, A., Sreenivasan, K., Singh, AK., & Radhamani J. (2013). Role of relative humidity in processing and storage of seeds and assessment of variability in storage behaviour in Brassica spp. And Eruca sativa. The scientific world Journal, 2013.

45. Kesar, G. (2013). Effect of irrigation with wastewater on the physiological properties and heavy metal content in Lepidium sativum L. and Eruca sativa (Mill.). Environment monitoring and assessment 185(7), 6209-6217.

46. Hussein, F. Z. (2013). Study the effect of Eruca sativa leaves extract on male fertility in albino mice. Al-Nahrain Journal of Science 16(1), 143-146.

47. Gupta, P., Ravi, I., & Sharma, V. (2013). Induction of β-1, 3- glucanase and chitinase activity in the defense response of Erua sativa plants against the fungal pathogen Alternaria brassicicola. Journal of Plant Interactions, 8(2), 155-161.

48. Indoria, A. K., Poonia, S. R., Sharma, K. L. (2013). Phytoextractability of Cd from soil by some oilseed species as affected by sewage sewage sludge and farmyard mauure. Communications in soil science and plant analysis, 44(22), 3444-3455.

49. Garg, G., & Sharma, Vinay. (2014). Eruca sativa (L.) : Botanical description, Crop improvement, and medicinal properties. Journal of herbs, spices & medicinal plants 20(2), 171 – 182.

50. Bell, L., & Wagstaff, C. (2014). Glucosinolates, Myrosinase hydrolysis products, and flavonols found in Rocket. Journal of agricultural and food chemistry, 62(20), 4481-4492.

51. Jyoti, U., & Malik, CP. (2014). Seed deterioration in Eruca sativa (Miller). Varieties: Comparative factors between seeds and leaves. International Journal for research in applied science and engineering technology, 2(11), 203-214.

52. Jat, B. L. & Jakhar, M. L. (2014). Phenotypic path co-efficient analysis in taramira (Eruca sativa L.) under three environment conditions. International Journal of Plant Sciences (Muzaffarnagar), 9(1), 231-233.

53. Jyoti, U., & Malik, CP. (2014). Seed deterioration in Eruca sativa (Miller). Varieties: Comparative factors between seeds and leaves. International Journal for research in applied science and engineering technology, 2(11), 203-214.

54. Khan, H. & Khan, K. M. (2014). Antiulcer effect of extract / fractions of Eruca sativa : Attenuation of urease activity. Journal of Evidence – Based Complementary & Alternative Medicine, 19(3), 176-180.

55. Zhi, Y. et. al. (2015). Influence of heavy metals on seed germination and early seedling growth in Eruca sativa Mill. American Journal of Plant Sciences, 6(05), 582.

56. Jalilian, J., & Khaliliaqdam, N. (2015). Effect of alternative temperatures on germination rate of Rocket seed. Iranian journal of seed research, 2(1).

57. Singh, P. et. al. (2015). Genetic variability for grain yield and its various components in taramira. Journal of plant science research, 31(2).

58. Mangwende, E. et. al. (2015). First report of white rust of rocket caused by Albugo candida in South Africa. Plant disease 99(2), 290-290.

59. Kamran, A. M. et. al. (2015). Effect of plant growth - promoting rhizobacteria inoculation on cadmium (Cd) uptake by Eruca sativa. Environmental Sciences and Pollution Research, 22(12), 9275 -9283.

60. Gehani, AL. I., Ismail, T. (2016). Effect of soil amendment on growth and physiological processes of rocket grown under salinity conditions. Australian journal of basic and applied sciences, 10(1), 15-20. Genetica 39, 1-24.

61. Nejadhasan, B. et. al. (2017). Studying the response of seed germination of neglected plant arugula to some environmental factors. Journal of plant production 24(2), 77-91.

62. Kumar, S. et. al. (2017). Physical and biochemical aspects of host plant resistance to mustard aphid, Lipaphis erysimi in rapeseed - mustard. Arthropod - Plant Interactions, 11(4), 551-559.

63. Kishore, L., Kaur, N., & Singh, R. (2018). Effect of kaempferol isolated from seeds of Eruca sativa on changes of pain sensitivity in streptozotocin-induced diabetic neuropathy. Inflammopharmacology, 26 (4), 993-1003.

64. Fatima, A. et. al. (2018). Scanning electron microscopy as a tool for authentication of oil yieldind seed. Microscopy research and technique 81(6), 624-629.

65. Mahmoud, A. W. M., & Taha, S. S. (2018). Main sulphur content in essential oil of Eruca sativa as affected by nano iron and nano zinc mixed with organic manure. Agriculture, 64(2).

66. Gabr, G. D. (2018). Significance of fruit and seed coat morphology in taxonomy and identification for some species of Brassicaceae. American journal of plant sciences 9(03), 380.

67. Fatima, A. et. al. (2018). Scanning electron microscopy as a tool for authentication of oil yieldind seed. Microscopy research and technique 81(6), 624-629.

68. Gugliandolo, A. et. al. (2018). Eruca sativa seed extract : A novel natural product able to counteract neuroinflammation. Molecular Medicine Reports, 17(5), 6235 – 6244.

69. Mashi, K. S. & Dheyab, S. D. (2018). Effect of Eruca sativa leaves extracts on Osteoporosis induced by phosphoric acid in adult male rabbits. Indian Journal of Natural Sciences, 8, 13098-13106.

70. Choi, J. Y., Kruse J., Thines, M. (2018). Hyaloperenospora erucae sp. non. (Peronosporaceae; Oomycota), the downy mildew pathogen of arugula (Eruca sativa). European Journal of Plant Pathology, 151(2), 549-555.

71. Plaksenkova, I. et. al. (2019). Effects of Fe304 nanoparticle stress on the growth and development of rocket. Journal of nanomaterials, 2019.

72. Mahawar, L., & Shekhawat, S. G. (2019). EsHO 1 mediated mitigation of NaCl induced oxidative stress and correlation between ROS, antioxidants and HO 1 in seedling of Eruca sativa. Physiology and Molecular Biology of Plants, 25(4), 895 - 904.

73. Jaafar, N. S. & Jaafar, I. S. (2019). Pharmacognostical and pharmacological properties and pharmaceutical preparations. Asian Journal of Pharmaceutical and Clinical Research, 12(3), 39-45.

74. Barazani, O. et. al. (2019). Natural variation in flower color and scent in populations of Eruca sativa affects pollination behaviour of honey bee. Journal of Insect Science, 19(3).

75. Shakeel, M. et. al. (2019). Insect pollinators diversity and abundance in Eruca sativa Mill. and Brassica rapa L. crops. Saudi journal of biological sciences, 26(7), 1704- 1709.

76. Kumar, A. et. al. (2019). Growth, yield and quality improvement of flax (Linum usitattisimum L.) grown under tarai region of Uttarakhand, India through integrated nutrient management practices. Industrial Crops and Products, 140, 111710.

77. EL-Wakeel, M. A. et. al. (2019). Bioherbicidal activity of Eruca sativa fresh shoot aqueous extract for the management of two annual weeds associating Pisum sativum plants. Bulletin of the National Research Centre 43(87), 967.

78. Afsar, S. et. al. (2020). Evaluation of salt tolerance in Eruca sativa accessions based on morpho- physiological traits. Peer J, 8, e9749.

79. Altwaijry, N. et. al. (2020). Therapeutic effects of rockets seeds against testicular toxicity and oxidative stress caused by silver nanoparticles injection in rats. Environmental toxicology, 35(9), 952-960.

80. Bakhshandeh, E. et. al. (2020). Quantification of the effect of environmental factors on seed germination and seedling growth of rocket using mathematical models. Journal of plant growth regulation, 39(1), 190- 204.

81. Pane, C. et. al. (2020). Managing rhizoctonia damping off of rocket seedlings by drench application of bioactive potato leaf phytochemical extracts. Biology, 9(9), 270.

82. Bonvicini, F. et. al. (2020). Effect of Lactobacillus acidophilus fermented broths enriched with Eruca sativa seed extracts on intestinal barrier and inflammation in a co- culture system. Nutrients 12(10), 3064.

83. Khan, U. A. et. al. (2020). Production of organic fertilizers from rocket seed, chicken peat and Moringa olifera leaves for growing linseed under water deficit stress. Sustainability, 13(1), 59.

84. Pashanezhad, M. Z. (2020). Genetic variation of Eruca sativa L. genotypes revealed by agromorphological traits and ISSR molecular markers. Industrial crops and products 145, 111992.

85. Santiago, EM. F. et. al. (2020). Biochemical basis of differential selenium tolerance in arugula (Eruca sativa Mill.) and lettuce (Lactuca sativa L.). Plant Phisiology and Biochemistry, 157, 328-338.

86. Khator, K., Mahawar, L. & Shekhawat G. S. (2020). NaCl induced oxidative stress in legume crops of Indian Thar Desert: an insight in the cytoprotective role of HO1, NO and antioxidants. Physiology and Molecular Biology of Plants, 26(1), 51-62.

87. Khaliq, B. et. al. (2021). Eruca sativa seed napin structural insights and thorough functional characterization. Scientific reports, 11(1), 1-13.

88. Elmardy, N. A. (2021). Photosynthetic performance of rocket grown under different regimes of light intensity, quality, and photoperiod. Plos one 16(9), 1-19.

89. Abd – Elsalam, R. M. et. al. (2021). Eruca sativa seed extract modulates oxidative stress and apoptosis and up- regulates the expression of Bcl-2 and Bax genes in acrylamide - induced testicular dysfunction in rats. Environmental Science and Pollution Research, 28(38), 53249 -53266.

90. Nanetti, A. et. al. (2021). Seed meals from Brassica nigra and Eruca sativa control artificial Nosema ceranae infections in Apis mellifera. Microorganisms, 9(5), 949.

91. Jamal, J. et. al. (2021). Internet of things monitoring of rocket (Eruca sativa) growth supplemented by LEDs lighting. Sensing and Bio-Sensing Research 34, 100450.

92. Mashhoor, V. M., Mikani, A., Mehrabadi, M., & Moharramipour, S. (2021). Antifeedant activity of nanoemulsion formulation of arugula Eruca sativa oil on elm leaf beetle Xanthogaleruca luteola (Coleoptera : Chrysomelidae). Journal of Agricultural Science and Technology, 23(1), 125-136.

93. Keyata, O. E. et. al. (2021). Phytochemical contents, antioxidant activity and functional properties of Raphanus sativus L, Eruca sativa L. and Hibiscus sabdariffa L. growing in Ethiopia. Heliyon, 7(1), e05939.

94. Teixeira, A. F. et. al. (2022). Chemical analysis of Eruca sativa ethanolic extract and its effects on hyperuricaemia. Molecules, 27(5), 1506.

95. Khan, S. et. al. (2022). Quantifying temperature and osmotic stress impact on seed germination rate and seedling growth of Eruca sativa Mill. Life 12(3), 400.

96. Gadow, HS., & Fakeeh, M. (2022). Green inhibitor of carbon steel corrosion in 1 M hydrochloric acid: Eruca sativa seed extract (experimental and theoretical studies). RSC Advances, 12(15), 8953-8986.

97. Cuce, M., & Muslu, S. A. (2022). Sodium nitroprusside mediates attenuation of paraquat-mediated oxidative stress in Eruca sativa in vitro. Physiology and Molecular Biology of Plants, 28(1), 289-299.

98. Maria Cristina Sorrentino et al. (2023)"Evaluation of morpho-physiological responses and genotoxicity in Eruca sativa (Mill.) grown in hydroponics from seeds exposed to X-rays" PeerJ. 2023; 11: e15281. Published online 2023 Apr 26. doi: 10.7717/peerj.15281 PMCID: PMC10148638 PMID: 37128204.

99. Sona S. El-Nwehy et al. (2023) "Improvement of (Eruca sativa Mill) yield, oil, chemical constituents and antioxidant activity utilizing a by-product of yeast production (CMS) with zinc and boron under salinity stress conditions" Oil Crop Science Volume 8, Issue 4, October 2023, Pages 218-227.

100. ÖZKAN, AYŞE and ÜNLÜ, HALİME (2024) "Chitosan application improves yield and quality of rocket (Eruca sativa)," Turkish Journal of Agriculture and Forestry: Vol. 48: No. 2, Article 11. https://doi.org/10.55730/1300-011X.3181 Available at: https://journals.tubitak.gov.tr/agriculture/vol48/iss2/11.

101. Abd – Elsalam, R. M. et. al. (2021). Eruca sativa seed extract modulates oxidative stress and apoptosis and up- regulates the expression of Bcl-2 and Bax genes in acrylamide - induced testicular dysfunction in rats. Environmental Science and Pollution Research, 28(38), 53249 -53266.

102. Afsar, S. et. al. (2020). Evaluation of salt tolerance in Eruca sativa accessions based on morpho- physiological traits. Peer J, 8, e9749.

103. Alam, S. M. et. al. (2007). Eruca sativa seeds possess antioxidant activity and exert a protective effect on mercuric chloride induced renal toxicity. Food and chemical toxicology , 45(6), 910-920.

104. Allard, R.W. (1960). Principles of Plant Breeding. John Willey & Sons. Inc. N.Y.

105. Alqasoumi, S. et. al. (2009). Rocket: A salad herb with potential gastric anti-ulcer activity. World Journal of Gastroenterology: WJG, 15(16), 1958.

106. Altwaijry, N. et. al. (2020). Therapeutic effects of rockets seeds against testicular toxicity and oxidative stress caused by silver nanoparticles injection in rats. Environmental toxicology, 35(9), 952-960.

107. Al-Whaibi, H. M. et. al. (2012). Influence of plant growth regulators on growth performance and photosynthetic pigments status of Eruca sativa Mill. Journal of Medicinal Plants Research, 6(10), 1948 – 1954.

108. Arasu, A. T. (1968). Self – incompatibility in Angiosperm: A Review

109. Asharaf, M. A., & Sarwar, G. (2002). Salt tolerance potential in some members of Brassicaceae physiological studies on water relations and mineral contents. Prospects for saline agriculture, 237- 245.

110. Ashraf, M. Y., & Sarwar, G. (2002). Salt tolerance potential in some members of Brassicaceae physiological studies on water relations and mineral contents. Prospects of saline agriculture, 237-245.

111. Bakhshandeh, E. et. al. (2020). Quantification of the effect of environmental factors on seed germination and seedling growth of rocket using mathematical models. Journal of plant growth regulation, 39(1), 190- 204.

112. Barazani, O. et. al. (2019). Natural variation in flower color and scent in populations of Eruca sativa affects pollination behaviour of honey bee. Journal of Insect Science, 19(3).

113. Barillari, J. et. al. (2005). Direct antioxidant activity of purified glucoerucin, the dietary secondary metabolite contained in rocket seeds and sprouts. Journal of Agriculture and food chemistry, 53(7), 2475- 2482.

114. Bateman, A. J. (1965). Self incompatibility systems in Angiosperms. III. Cruciferae. Heredity 9 : 53 – 68.

115. Bell, L., & Wagstaff, C. (2014). Glucosinolates, Myrosinase hydrolysis products, and flavonols found in Rocket. Journal of agricultural and food chemistry, 62(20), 4481-4492.

116. Bennett, N. R. et. al. (2007). Identification and quantification of glucosinolates in sprouts derived from seeds of wild Eruca sativa and Diplotaxis tenuifolia L. Journal of agricultural and food chemistry 55(1), 67-74.

117. Berba, J. Kenneth & Uchanski, E. M. (2012). Post harvest physiology of microgreens. J.

118. Bonvicini, F. et. al. (2020). Effect of Lactobacillus acidophilus fermented broths enriched with Eruca sativa seed extracts on intestinal barrier and inflammation in a co- culture system. Nutrients 12(10), 3064.

119. Bozokalfa, K. M. et. al. (2011). Evaluation of phenotypic diversity and geographical variation of cultivated and wild rocket plant. Plant genetic resources 9(3), 454- 463.

120. Brewbaker, J. L. (1957) Pollen cytology and self - incompatibility systems in plants. J. Heredity 48, 271-277.

121. Brewbaker, J. L. (1957). Self - incompatibility in Angiosperms. Heredity 11 : 271- 278.

122. Brewbaker, J. L. (1964) . Agricultural Genetics. Prentice - Hall inc., England Clifts, N. J. 1964.

123. Bukhsh, E., Malik, A. S., & Ahmad, S. S. (2007). Estimation of nutritional value and trace elements content of Carthamus oxyacantha, Eruca sativa and Plantago ovate. Pakistan Journal of Botany, 39(4), 1181.

124. Chakrabarti, H. M., & Ahmad, R. (2009). Investigation possibility of using least desirable edible oil of Eruca sativa L., in biodiesel production. Pakistan Journal of Botany, 41(1), 481-7.

125. Chandler, J. O. (2020). Rocket science: The effect of spaceflight on germination physiology, ageing and transcriptome of Eruca sativa seeds. Life 10(4), 49.

126. Charlesworth, D. & Charlesworth, B. (1979). The evolution and breakdown of S - allele systems. Heredity 43, 41- 55 .

127. Choi, J. Y., Kruse J., Thines, M. (2018). Hyaloperenospora erucae sp. non. (Peronosporaceae; Oomycota), the downy mildew pathogen of arugula (Eruca sativa). European Journal of Plant Pathology, 151(2), 549-555.

128. Crowe, L. K. (1964). The evolution of outbreeding in plants. I. The angiosperms. Heredity 19, 435- 457.

129. Cuce, M., & Muslu, S. A. (2022). Sodium nitroprusside mediates attenuation of paraquat-mediated oxidative stress in Eruca sativa in vitro. Physiology and Molecular Biology of Plants, 28(1), 289-299.

130. Davenport, C. B. (1908) . Degeneration, albino and inbreeding. Science. 28, 454- 455.

131. Dayal, N. & Prasad, C. (1983) . Genetic Regulation of Chromocentres in Radish (R. sativa L.) Cytologia, 48, 245- 252.

132. Dayal, N. (1974 - 75) . Studies of fertility in the inbred lines of radish and their hybrids. J. Cytol. Genet, 9-10, 4-12.

133. Dayal, N. (1975). Fertilization value in the inbred lines of radish and their hybrids. Ind. J. Agric. Sci, 45, 467-469.

134. Dayal, N. (1977). Cytogenetical studies in the inbred lines of radish (Raphanus sativus L. ver. Redicola Pers.) and their hybrids. II. Genetic regulation of chiasma frequency. Ibid, 42, 273- 278.

135. Dayal, N. (1983). Inheritance of colour & shape of Root in Radish . Eucarpia . Cruc. New. L, 8, 10.

136. Dobzhansky, Th. (1950). Mendelian populations and their evolution. Amer. Naturalist, 84, 401- 492.

137. Dobzhansky, Th. (1957). Mendelian populations as genetic systems. Cold Spring Harbor Symp. Quant. Biol, 22, 385-400.

138. East, E. M. & Jones, D. F. (1919). Inbreeding and outbreeding, their genetics and sociological signification. Phil. Lond. East, E. M. (1936). Hetrosis. Genetics, 21, 376 -397.

139. El.- Bayomi, A. S. (1975). Heterochromatin in anthers of Reseda arabica . Cytologia, 40, 45- 51.

140. Elmardy, N. A. (2021). Photosynthetic performance of rocket grown under different regimes of light intensity, quality, and photoperiod. Plos one 16(9), 1-19.

141. EL-Wakeel, M. A. et. al. (2019). Bioherbicidal activity of Eruca sativa fresh shoot aqueous extract for the management of two annual weeds associating Pisum sativum plants. Bulletin of the National Research Centre 43(87), 967.

142. Fagbenro, O. A. (2004). Soyabean meal replacement by roquette seed meal as protein feedstuff in diets for African Catfish, Clarias gariepinus (Burchell 1822), fingerlings. Aquaculture research, 35(10), 917-923.

143. Fatima, A. et. al. (2018). Scanning electron microscopy as a tool for authentication of oil yieldind seed. Microscopy research and technique 81(6), 624-629.

144. Fazli, IS., Abdin, MZ., Jamal, A., & Ahmad, S. (2005). Interactive effect of sulphur and nitrogen on lipid accumulation and acetyl- CoA concentration and acetyl - CoA carboxylase activity in developing seeds of oilseed crops. Plant science 168(1). 29 – 36.

145. Gabr, G. D. (2018). Significance of fruit and seed coat morphology in taxonomy and identification for some species of Brassicaceae. American journal of plant sciences 9(03), 380.

146. Gadow, HS., & Fakeeh, M. (2022). Green inhibitor of carbon steel corrosion in 1 M hydrochloric acid: Eruca sativa seed extract (experimental and theoretical studies). RSC Advances, 12(15), 8953-8986.

147. Garg, G., & Sharma, Vinay. (2014). Eruca sativa (L.) : Botanical description, Crop improvement, and medicinal properties. Journal of herbs, spices & medicinal plants 20(2), 171 – 182.

148. Gehani, AL. I., Ismail, T. (2016). Effect of soil amendment on growth and physiological processes of rocket grown under salinity conditions. Australian journal of basic and applied sciences, 10(1), 15-20.

149. Genetica 39, 1-24.

150. Ghavampoor, M. . et. al. (2015). Yield, morphological traits and nitrogen use efficiency of Eruca sativa as affected by irrigation, plant density and nitrogen fertilization. Biological Forum – An International Journal.

151. Gowda, C. L. L. & Bahi , P. N. (1979). Combining ability in Chickpea. India J. Genet, 38 (2), 245- 251.

152. Grafius, F. (1959). Heterosis in barley. Agron. J, 51, 551-554.

153. Gugliandolo, A. et. al. (2018). Eruca sativa seed extract : A novel natural product able to counteract neuroinflammation. Molecular Medicine Reports, 17(5), 6235 – 6244.

154. Gulfraz, M. et. al. (2011). Phytochemical analysis and antibacterial activity of Eruca sativa seed. Pak. J. Bot, 43 (2), 1351-1359.

155. Gupta, A. K., Agarwal, H. R. & Dahama, A. K. (1998). Taramira: A potential oilseed crop for the marginal lands of Rajasthan, India. Taramira: a potential oilseed crop for the marginal lands of Rajasthan, India, 2, 687- 691.

156. Gupta, M. P. & Singh, R. B. (1969). Variability and correlation studies in green gram (Phaseolus aurens Roxb). Indian J. agric, Sci. 39, 482-493.

157. Gupta, P., Ravi, I., & Sharma, V. (2013). Induction of β-1, 3- glucanase and chitinase activity in the defense response of Erua sativa plants against the fungal pathogen Alternaria brassicicola. Journal of Plant Interactions, 8(2), 155-161.

158. Gupta, R. R. & Ahmad, Z. (1979) . Genetic parameters in macaroni wheat. Indian J. Genet, 39 (2), 263-269.

159. Hasoda , T., Namai, H. & Gols, J. 1963. On the Breeding of B. napus obtained from artificially induced Amphidiploids III. On the Breeding of synthetic rutabaga (B. napus) var. rapifera. Japan. J. Breed, 13, 90- 105.

160. Herberd, D. J. & Mc Arthur, E .D. (1972). Two partially fertile hybrids in the Brassica. Heredity, 28, 253- 254.

161. Heslop – Harisson, J.(1975). Incompatibility & the pollen - stigma interaction. Ann. Rev. Pl. Physiol, 26, 403- 425.

162. Hosoda, T. (1961). Studies on the Breeding of New types of napus crops by means of artificial synthesis in Genomes of Genus Brassica. Mam . Fac. Agr . Tokyo Univ. Edu, 7, 1 – 94.

163. Hussein, F. Z. (2013). Study the effect of Eruca sativa leaves extract on male fertility in albino mice. Al-Nahrain Journal of Science 16(1), 143-146

164. Indoria, A. K., Poonia, S. R., Sharma, K. L. (2013). Phytoextractability of Cd from soil by some oilseed species as affected by sewage sewage sludge and farmyard mauure. Communications in soil science and plant analysis, 44(22), 3444-3455.

165. Jaafar, N. S. & Jaafar, I. S. (2019). Pharmacognostical and pharmacological properties and pharmaceutical preparations. Asian Journal of Pharmaceutical and Clinical Research, 12(3), 39-45.

166. Jalilian, J., & Khaliliaqdam, N. (2015). Effect of alternative temperatures on germination rate of Rocket seed. Iranian journal of seed research, 2(1).

167. Jamal, J. et. al. (2021). Internet of things monitoring of rocket (Eruca sativa) growth supplemented by LEDs lighting. Sensing and Bio-Sensing Research 34, 100450.

168. Jat, B. L. & Jakhar, M. L. (2014). Phenotypic path co-efficient analysis in taramira (Eruca sativa L.) under three environment conditions. International Journal of Plant Sciences (Muzaffarnagar), 9(1), 231-233.

169. Jing, J. et. al. (2009). Analysis of phytochemical composition and chemoprotective capacity of rocket (Eruca sativa and Diplotaxis tenuifolia) leafy salad following cultivation in different environments. Journal of Agriculture and Food Chemistry 57(12), 5227-34.

170. Jones, D. F. (1918). The effect of inbreeding and cross - breeding upon development. Conn. Agr. Exp. Sta. Bull, 207. \

171. U., & Malik, CP. (2014). Seed deterioration in Eruca sativa (Miller). Varieties: Comparative factors between seeds and leaves. International Journal for research in applied science and engineering technology, 2(11), 203-214.

172. Jyoti, U. & Malik, C.P. (2014). Seed deterioration in Eruca sativa (Miller) Thell. Varieties: Comparative factors between seeds and leaves. International Journal for Research in Applied Science and Engineering Technology, 2(11), 203-214

173. Kamaya, T. & Honata, K. (1970). Induction of Haploid Plants from Pollen Grains of Brassica. Japan. J. Breed, 20, 82-87.

174. Kamaya, T. & Takahashi, N. (1972). The effect of Inorganic Salts on fusion of Protoplasts from Root and Leaves of Brassica species . Japan. J. Genet, 47, 215-217.

175. Kamran, A. M. et. al. (2015). Effect of plant growth - promoting rhizobacteria inoculation on cadmium (Cd) uptake by Eruca sativa. Environmental Sciences and Pollution Research, 22(12), 9275 -9283.

176. Kasem, WT., Ghareeb, A., & Marwa, E. (2011). Seed morphology and seed coat sculpturing of 32 taxa of famiy Brassicaceae. Journal of American science, 7(2), 166-178.

177. Kavga, A. et. al. (2018). Growth and physiological characteristics of lettuce and rocket plants cultivated under photovoltaic panels. Notulae Botanicae Horti Agrobotanici cluj-Napoca, 46(1), 206-212.

178. Kesar, G. (2013). Effect of irrigation with wastewater on the physiological properties and heavy metal content in Lepidium sativum L. and Eruca sativa (Mill.). Environment monitoring and assessment 185(7), 6209-6217.

179. Keyata, O. E. et. al. (2021). Phytochemical contents, antioxidant activity and functional properties of Raphanus sativus L, Eruca sativa L. and Hibiscus sabdariffa L. growing in Ethiopia. Heliyon, 7(1), e05939.

180. Khaliq, B. et. al. (2021). Eruca sativa seed napin structural insights and thorough functional characterization. Scientific reports, 11(1), 1-13.

181. Khan, H. & Khan, K. M. (2014). Antiulcer effect of extract / fractions of Eruca sativa : Attenuation of urease activity. Journal of Evidence – Based Complementary & Alternative Medicine, 19(3), 176-180.

182. Khan, S. & Qurainy. F. Al. (2009). Mutagenic effect of sodium azide on seed germination of Eruca sativa (L.). Australian Journal of Basic and Applied Sciences 3(4), 3081-3087.

183. Khan, S. et. al. (2022). Quantifying temperature and osmotic stress impact on seed germination rate and seedling growth of Eruca sativa Mill. Life 12(3), 400.

184. Khan, U. A. et. al. (2020). Production of organic fertilizers from rocket seed, chicken peat and Moringa olifera leaves for growing linseed under water deficit stress. Sustainability, 13(1), 59.

185. Khator, K., Mahawar, L. & Shekhawat G. S. (2020). NaCl induced oxidative stress in legume crops of Indian Thar Desert: an insight in the cytoprotective role of HO1, NO and antioxidants. Physiology and Molecular Biology of Plants, 26(1), 51-62.

186. Kim, J. S., & Ishii G. (2006). Glucosinolate profiles in the seeds, leaves and antioxidative activities of intact plant powder and purified 4. Soil science and plant nutrition, 52(3), 394-400.

187. Kishore, L., Kaur, N., & Singh, R. (2018). Effect of kaempferol isolated from seeds of Eruca sativa on changes of pain sensitivity in streptozotocin-induced diabetic neuropathy. Inflammopharmacology, 26 (4), 993-1003

188. Kumar, A. et. al. (2019). Growth, yield and quality improvement of flax (Linum usitattisimum L.) grown under tarai region of Uttarakhand, India through integrated nutrient management practices. Industrial Crops and Products, 140, 111710.

189. Kumar, G. et. al. (2009). Physiological responses among Brassica species under salinity stress show strong correlation with transcript abundance for SOS pathway related genes. Journal of plant physiology, 166(5), 507-520.

190. Kumar, S. et. al. (2017). Physical and biochemical aspects of host plant resistance to mustard aphid, Lipaphis erysimi in rapeseed - mustard. Arthropod - Plant Interactions, 11(4), 551-559.

191. Labana, K. S. et. al. (1990). Taramira Ludhiana Composite -2 (TMLC -2) of Eruca sativa. Journal of Research, Punjab Agricultural University, 23(3).

192. Lal, B. (1972). Diallet analysis of grain yield and some other quantitative traits in Bengal gram (Cicer acrietinum L.) . M. Sc. (Ag.) Thesis, Punjab Agric. Univ. Ludhiana.

193. Larran, S., Ronco, L., Monaco, C., & Andreau, RH. (2006). First report of Peronospora parasitica on rocket in Argentina. Australasian plant pathology 35(3), 377-378.

194. Lerner, I. M. (1954). Genetic Homostasis . John Willey & Sons . N. Y. Lewis, D. (1954). Comparative incompatibility in angiosperms & fungi. Adv. Genet, 6, 235- 285.

195. Lima de Faria, A., Jaworska, H. (1968). Late DNA synthesis in heterochromatin . Nature, 217, 138 -142.

196. Linskens, H. F. (1965). Biochemesty of incompatability. Proc. 11th Intern. Cong. Genet, 3, 629 – 636.

197. Lundqvist, A. (1965). The genetics of incompatability. Proc. 11th. Intern. Cong. Genet, 3, 637– 647.

198. Mahawar, L., & Shekhawat, S. G. (2019). EsHO 1 mediated mitigation of NaCl induced oxidative stress and correlation between ROS, antioxidants and HO 1 in seedling of Eruca sativa. Physiology and Molecular Biology of Plants, 25(4), 895 -904.

199. Mahmood, S. et. al. (2004). Comparative performance of Brassica napus and Eruca sativa under water deficit conditions : An assessment of selection criteria. J. Res. Sci, 14(4), 439-446.

200. Mahmoud, A. W. M., & Taha, S. S. (2018). Main sulphur content in essential oil of Eruca sativa as affected by nano iron and nano zinc mixed with organic manure. Agriculture, 64(2).

201. Maiti, R., Rodriguez, HG. & Kumari A. (2016). Nutrient profile of native woody species and medicinal plants in northeastern Maxico: A Synthesis. J Bioprocess Biotech, 6(283), 2.

202. Maliwal, P. L. & Mundra, S. L. (1990). Effect of inter and intra row spacing on yield and quality of taramira (Eruca sativa L.). International journal of tropical agriculture, 8(3), 223-225.

203. Mangwende, E. et. al. (2015). First report of white rust of rocket caused by Albugo candida in South Africa. Plant disease 99(2), 290-290.

204. Manohar, S. S., & Sharma, K. C. (2008). Genetic variability and characters association analysis in Taramira (Eruca sativa Mill.). Madras Agricultural Journal, 95(7/12), 278-282.

205. Mashhoor, V. M., Mikani, A., Mehrabadi, M., & Moharramipour, S. (2021). Antifeedant activity of nanoemulsion formulation of arugula Eruca sativa oil on elm leaf beetle

206. Xanthogaleruca luteola (Coleoptera : Chrysomelidae). Journal of Agricultural Science and Technology, 23(1), 125-136.

207. Mashi, K. S. & Dheyab, S. D. (2018). Effect of Eruca sativa leaves extracts on Osteoporosis induced by phosphoric acid in adult male rabbits. Indian Journal of Natural Sciences, 8, 13098-13106.

208. Mather, K. (1955). The genetical basis of heterosis. Proc. Roy. Soc. (Lond) B, 144, 143-150.

209. Michael, H., Shafik, R. E., & Rasmy, G. E. (2011). Studies on the chemical constituents of fresh leaf of Eruca sativa extract and its biological activity as anticancer agent in vitro. Journal of medicinal plant research 5(7), 1184-1191.

210. Missiry –EL, MA., & Gindy – EL, AM. (2000). Amelioration of alloxan induced diabetes mellitus and oxidative stress in rats by oil of Eruca sativa seeds. Annals of Nutrition and Metabolism, 44(3), 97-100.

211. Miyazawa, M., Maehara, T. & Kurose, K. (2002). Composition of the essential oil from the leaves of Eruca sativa. Flavour and fragrance journal, 17(3), 187-190.

212. Mohammad, A., & Ahmad, S. (1945). A note on the essential oil of mustard in Brassica species and Eruca sativa. Indian Journal of Agricultural Sciences, 15, 181- 183.

213. Mumtaz, A. S. (2013). Genetic divergence in taramira (Eruca sativa L.) germplasm based quantitative and qualitative characters. Pakistan journal of Botany, 45(SI), 375 -381.

214. Nagal, W. (1976). Nuclear organization. Ann. Bot. Plant Physiol, 27, 39-69.

215. Nakai, Y. (1977). Variations of esterase isoenzymes & some soluble proteins in diploids & their induced autotertraploids in plants. Jap. J. Genet, 52, 171 -182.T

216. Nakai, Y. (1977). Variations of esterase isoenzymes & some soluble proteins in diploids & their induced autotetraploids in Plants. Jap. J. Genet, 52, 171-182.

217. Nanetti, A. et. al. (2021). Seed meals from Brassica nigra and Eruca sativa control artificial Nosema ceranae infections in Apis mellifera. Microorganisms, 9(5), 949.

218. Narbut, S.I. (1961). A dwarf form of radish. Isslayed Genet. 1 : 48 -49 (In Russian C English summary).

219. Nejadhasan, B. et. al. (2017). Studying the response of seed germination of neglected plant arugula to some environmental factors. Journal of plant production 24(2), 77-91.

220. Nicola, S., Fontana, E., Tibaldi, G., & Zhan, L. (2009). Qualitative and physiological response of minimally processed rocket (Eruca sativa Mill.) to package filling amount and shelf – life temperature. VI International Postharvest Symposium, 877, 611- 618.

221. Nielsen, T., Bergstorm, B., & Borch, E. (2008). The origin of off – odours in packaged rucola. Food chemistry, 110(1), 96-105.

222. Nielsen, T., Bergstrom, B., & Borch, E. (2008). The origin of off – odours in packaged rucola (Eruca sativa). Food chemistry, 110(1), 96 – 105.

223. Nishi, S., kuriyama, T. and Hiraoka, T. (1964). Study on the breeding of crucifer vegetables by interspecific and intergeneric hybridization. I. Special reference to the utilization of matroclinous hybrids accompanied with pseudogam in those hybridizations. Bull. Hort. Res. Sta. Japan Ser, 3, 161-150. (In Japanese C English summary).

224. Ozdener, Y. & Ayadin, B. K. (2010). The effect of zinc on the growth and physiological and biochemical parameters in seedling of Eruca sativa L. Acta Physiologiae Plantarum , 32(3), 469-476.

225. Pal, B. P. & Sikka S. M. (1956). Exploitation of hybrid vigour in the improvement of crop plants. India J. Genet, 16, 98.

226. Pane, C. et. al. (2020). Managing rhizoctonia damping off of rocket seedlings by drench application of bioactive potato leaf phytochemical extracts. Biology, 9(9), 270.

227. Panicker (S) , I. (1989). Cytogenetical and mutational studies of the cultivated radish (Raphanus sativus L.) Ph. D. Thesis, Ranchi University , Ranchi.

228. Panicker , I. & Dayal, N. 1985. Effect of vincristine on chromocentre frequency on radish. Eucarpia Cruciferae Nawel, 10, 35.

229. Pashanezhad, M. Z. (2020). Genetic variation of Eruca sativa L. genotypes revealed by agromorphological traits and ISSR molecular markers. Industrial crops and products 145, 111992.

230. Plaksenkova, I. et. al. (2019). Effects of Fe304 nanoparticle stress on the growth and development of rocket. Journal of nanomaterials, 2019.

231. Prakash, S. (1980). Cruciferous oilseeds in India. Cruciferous oilseeds in India, 151-163.

232. Prasad, C. (1980). Cytogenetics investigations in Indian Radishes. Ph. D. Thesis , Ranchi University , Ranchi.

233. Prasad, K., Panicker, I. and Dayal, N. (1986). Chromocentres in the American radishes. Eucarpia Cruciferae Nawel, 11, 27-28.

234. Qurainy, A. F. (2009). Effects of sodium azide on growth and yield traits of Eruca sativa (L.). World Applied Sciences Journal, 7(2), 220-226.

235. Rajan, S. S., Hardas, M. W. & Parthasarathy, N. (1950) . Breakdown of tetraploidy in colchicines induced autotetraploid Eruca sativa Lam. Indian Journal of Genetics and Plant Breeding, 10, 43- 55.

236. Ram, J. & Panwar , D.V.S. (1970). Intraspecific divergence in Rice. Indian J. Genet, 30 (1), 1-10.

237. Randhawa, N. & Sharma, S. K. (2008). Control of root – knot nematode (Meloidogyne incognita) in nursery beds of tomato by soil amendment with Brassica rapa, Brassica juncea, Brassica napus and Eruca sativa plants. Pakistan Journal of Nematology, 26(1), 91-96.

238. Reddy, R. P., Azeem , M. A., Rao, K.V. & Rao, N. G. P. (1979). Combining ability and index selection in F2 generation of Pigeon Pea Crosses. Indian J. Genet, 39(2), 247-254.

239. Richard, R. A. & Thurling, N. (1973). The genetics of self - incompatibility Brassica campestris L. II. Genotype & environmental modifications, S. locus control. Genetica, 44, 439 -453.

240. Sampson, D. R. (1957). The genetics of self - incompatibility in radish. J. Heredity, 48, 26 -29.

241. Sampson, D. R. (1964). One locus self - incompatibility in Raphanus raphanistrum. Canad. J. Genet. Cytol, 6, 435-445.

242. Santiago, EM. F. et. al. (2020). Biochemical basis of differential selenium tolerance in arugula (Eruca sativa Mill.) and lettuce (Lactuca sativa L.). Plant Phisiology and Biochemistry, 157, 328-338.

243. Sarashima, M. (1964). Studies on the breeding of artificially synthesized rape (Brassica napus) I. F1 Hybrids between B. campestris group and B. oleraceae group and the derived F1 plants. Japan J. Breed, 14, 226-236.

244. Sastry, EV. (2003). Improvement in Eruca sativa L. Aricultural Reviews, 24(4), 235-249.

245. Sears , E. R. (1937). Cytological phenomena connected with self - sterility in the flowering plants. Genetica, 33, 439- 446 .

246. Shakeel, M. et. al. (2019). Insect pollinators diversity and abundance in Eruca sativa Mill. and Brassica rapa L. crops. Saudi journal of biological sciences, 26(7), 1704- 1709.

247. Sharma, D. K., Rana, D. S., Joshi, H. C. (2007). Evaluation of sugarcane (Saccharum officinarum) - based industrial waste and litter fall of jatropha (Jatropha curcas) for nutrient management in oliferous rocket salad (Eruca sativa). Indian Journal of Agronomy, 52(3), 160-163.

248. Shull, G. H. (1911). The genotypes of maize . Am. Naturalist, 45, 234-252.

249. Sikka, S.M. (1940), Cytogenetics of Brassica Hybrids and species. J. Genet, 40, 441-509.

250. Singh, B. P. (1950). Effect of sowing time and seed rate on the seed and oil yield of taramira. Telhan Patrika, 2(2), 1-5.

251. Singh, H. B. (1962). Exploitation of hybrid vigour in vegetables. I.C. A. R. Research Series No. 33.

252. Singh, K. B. & Malhotra, R.S. (1970). Interrelationship between yield and yield components in mungbean. Indian J. Genet, 30, 244-250.

253. Singh, P. et. al. (2015). Genetic variability for grain yield and its various components in taramira. Journal of plant science research, 31(2).

254. Singh, S. K. and Khanna, R. 1965. Physiological, biochemical and genetic basis of heterosis. Adv. Argon, 27, 123-174.

255. Singh, V. P. , Swaminathan, M. S. & Mehra, R. B. (1979). Divergence among dwarfs of cultivated Rice. Indian J. Genet, 39(2), 315 -321.

256. Stout, A. B. (1920) . Further experimental studies on self - incompatibility in hermaphrodite plants. J. Genet, 9, 85-129.

257. Stubbe, H. (1978). Heterosis. Jena.

258. Suma, A., Sreenivasan, K., Singh, AK., & Radhamani J. (2013). Role of relative humidity in processing and storage of seeds and assessment of variability in storage behaviour in Brassica spp. And Eruca sativa. The scientific world Journal, 2013.

259. Sun, W. et. al. (1999). Assessment on drought tolerance of Eruca sativa genotypes from northwestern China. Proc GCIRC 10th Int. Rapeseed Congr 4, 628.

260. Surikov, I. M. (1971). Genetics of intraspecies incompatibility of male gametophyte and style in flowering plants. Success of Modern Genetics, 4, 119-169. (In Russian C. English summary)

261. Takhtajan, A. L. (1955). Nekotorie voprocil teorii vida v alstematike sovremennikh I iskopaemikh rastanii. Sot. Jour, 40, 6 -15 (In Russian)

262. Tatebe, T. (1957). Further studies on the behaviour of incompatible pollen in the Japanese radish. J. Hort. Assoc . Japan, 26, 21-27

263. Tatebe, T.(1958) . Studies on the genetics of self & cross - incompatibility in the Japanese radish. J. Hort . Assoc. Japan, 27, 154-160.

264. Teixeira, A. F. et. al. (2022). Chemical analysis of Eruca sativa ethanolic extract and its effects on hyperuricaemia. Molecules, 27(5), 1506.

265. Timofeef - Ressovski, Svirezhev, N. V. , Yu, M. (1967). About genetic polymorphism in populations. Experimental and theoretical investigations. Genetica, 3, 10-16. (In Russian with English summery).

266. Tshetverikov, C. C. (1926) . On some moments of the evolutionary process from the view point of modern Genetics. J. Exp. Biol. Ser. A., 2, 1-10 (In Russian).

267. Turbin, N.V. (1971). Genetics of heterosis and the methods of plant breeding for combinig ability. In " Genetic Basis of Plant Breeding ". Academy of Sciences, USSR, Nauka, Moscow, 1971.

268. Vannini, C. et. al. (2013). Morphological and proteomic responses of Eruca sativa exposed to silver nanoparticles of silver nitrate. Plos one, 8(7), 68752.

269. Vilamil, J. M. P. (2002). Time of seed collection and germination in rocket, Eruca vesicaria (L.). Genetic Resources and Crop Evolution 45, 47-51.

270. Yaniv, Z., Schafferman, D., & Amar, Z. (1998). Tradition, uses and biodiversity of rocket in Israel. Economic botany 52(4), 394-400.

271. Yaniv, Z., Schafferman, D., & Amar, Z. (1998). Tradition, uses and biodiversity of rocket in Israel. Economic botany, 52(4), 394-400

272. Yildirim, E. et. al. (2019). Impact of cadmium and lead heavy metal stress on plant growth and physiology of rocket. Kahramanmaras sutcu imam Universitesi Tarim ve Doga Dergisi 22(6), 843-850.

273. Young Investing, 24(1), 5.

274. Zhi, Y. et. al. (2015). Influence of heavy metals on seed germination and early seedling growth in Eruca sativa Mill. American Journal of Plant Sciences, 6(05), 582.